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AC5555 Automatic Component Analyser

462

OPERATING INSTRUCTIONS

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AC5555 Automatic Component Analyser

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2.0 SULLIVAN AC5555 AUTOMATIC COMPONENT ANALYSER

3.0 GENERAL DESCRIPTION

3.1 Introduction

The Sullivan AC5555 Automatic Component Analyser is a mains operated, fourteen range, digital capacitance and inductance measuring system. It is capable of automatically choosing the correct range and function for any two-terminal component and hence measures the parallel capacitance and conductance or the series inductance and resistance over a wide range, at a test frequency of 1 kHz. Measurements may also be made in the manual mode. Dissipation factor may be displayed, derived from the measurements by a calculation method.

Digital systems features for both output and input signals are available on the rear panel.

A test jig AC5556 is available as an optional accessory and is suitable for the majority of applications. A lead set is also available for other applications.

3.2 Applications

The instrument is primarily intended for goods inwards and production use, where speed and ease of use are important, and may be used as part of an automatic or semi-automatic measurement system. The auto-function facility also makes the instrument particularly useful for the identification of unknown components or for use by semi-skilled operators.

3.3 Controls

All user controls are carried on the front panel. At the right-hand side of the panel there are three function switches: L/R, C/G and AUTO. When the instrument is switched on, it is in the fully automatic mode and the two lamp indicators AUTO FUNCTION and AUTO RANGE are illuminated. If the instrument is to be used in the auto-range mode only, one of the two function switches is to be depressed. The upper switch is used for the measurement of inductance and series resistance and the lower switch for the measurement of parallel capacitance and conductance. Each switch has a lamp indicator.

There are seven range switches, with lamp indicators, arranged horizontally. In the fully automatic mode or auto-range mode, it is not necessary to use any of these switches. However, by pushing one of these switches the instrument is locked into a particular range and function. This mode of operation may be more suitable for testing a batch of components which have nominally the same value, since the response time of the display is less than in the automatic mode. To return the instrument to the fully automatic mode, the AUTO switch is depressed.

To the left of the range switch bank is a dissipation factor ($\tan\delta$) switch. When this control is depressed the dissipation factor of the component under test is shown on the right-hand display. When this switch is pressed again, the resistance or conductance value is again displayed.

In the bottom right-hand corner of the front panel there is a further switch which, when in the lower position, causes a d.c. bias voltage to be applied to the component under test. This may be used for the measurement of particular types of tantalum electrolytic capacitors which must not be subjected to a reverse bias. The value of the voltage is 1,5 V on ranges 4 and 5, and 150 mV on range 6, giving a unidirectional signal. The switch is only operative on capacitance/conductance ranges 4, 5 and 6.

The power ON/OFF switch is located in the bottom left-hand corner of the front panel. When the instrument is turned ON the display is illuminated, and the instrument is ready for use.

Five terminals are provided for connection to the component under test. Connections may be made directly, via the test jig AC 5556, or via the special lead set. The two outer connections I+ and I− are the current terminals by which an alternating current of frequency 1 kHz is passed through the component. The two connections P+ and P− are the potential connections and measure the voltage across the component. The central terminal G is the guard terminal which is normally connected to the chassis of the test jig. When using the test jig AC 5556, all five terminals are used. Measurements may also be made in the two terminal mode, in which case the two pairs of outside terminals are shorted together (I+ to P+ and I− to P−) and connections made from the two current terminals. In order to obtain the most accurate results at the limits of the measurement range, certain precautions should be taken when making connections to the component. (See 'Measurement Techniques').

3.4 **Display**

The measured information is displayed on two light emitting diode displays, each having 4½ digits. The left-hand display shows the inductance or capacitance and the right-hand display the series resistance or parallel conductance, together with the correct decimal placement and unit. The full scale value on each display is 19999. The right-hand display also indicates the dissipation factor when the switch is depressed; the maximum indication is then 1.0000.

It should be noted that the unit of measurement of conductance is the Siemen, which is represented by S on the display. This unit is the S.I equivalent of the 'reciprocal ohm' or 'mho'.

3.5 **Accessories**

The following optional accessories are available:

Universal Component Jig AC5556	Part No. 6210–075

This jig is designed to accept discrete components, with axial or radial leads, up to 95 mm long. It is simple and quick to use, and plugs directly into the AC5555.

Lead Set	Part No. 6110–176
Rack mounting kit	22381–248
Set of Extension Cards (for servicing)	6110–177
Free Plug 29 way (for sockets 2 and 3)	25436–247
Free Plug 17 way (for socket 4)	25436–245

4.0 SPECIFICATION

Ranges

On each range both the real and imaginary parts are displayed simultaneously. Either capacitance with conductance or inductance with resistance may be measured. Maximum reading: 19999

Range	Capacitance	Conductance	Inductance	Resistance
0	200 pF	2 μS	200 H	2 MΩ
1	2 nF	20 μS	20 H	200 kΩ
2	20 nF	200 μS	2 H	20 kΩ
3	200 nF	2 mS	200 mH	2 kΩ
4	2 μF	20 mS	20 mH	200 Ω
5	20 μF	200 mS	2 mH	20 Ω
6	200 μF	2 S	200 μH	2 Ω

Resolution: 10 fF (10×10^{-15} F) and 10 nH

Dissipation Factor (tanδ): Up to 1.0000 on all ranges. Calculated as if at a precise frequency of 1 kHz.

Accuracy (at 20°C)

Capacitance and Inductance
Ranges 0 – 5: ± 0,1% of reading ± 1 digit ± 0,05% of G or R reading
Range 6: ± 0,2% of reading ± 1 digit ± 0,1% of G or R reading

Conductance and Resistance
Ranges 0 – 5: ± 0,1% of reading ± 1 digit ± 0,05% of C or L reading
Range 6: ± 0,2% of reading ± 1 digit ± 0,1% of C or L reading

Dissipation Factor
The dissipation factor is derived from the measurements and thus has the accuracies of those components, with an additional error of ± 0,1% ± 1 digit for the calculation.

Residuals at Terminals
Capacitance: ± 0,05 pF max.
Conductance: ± 0,2 nS max.
Inductance: + 100nH max.
Resistance: + 0,2 mΩ max.

Frequency of Measurement
1 kHz ± 0,5%

Measuring Conditions

Capacitance Ranges
Ranges 0 – 5: 1 V r.m.s at 1 kHz applied to unknown
Range 6: 100 mV r.m.s. at 1 kHz applied to unknown

Inductance Ranges
A constant current is applied to the component. The values are as follows:

Range	0	1	2	3	4	5	6
Current (rms)	1 μA	10 μA	100 μA	1 mA	10 mA	100mA	100mA

Stability
The long term stability, without recalibration, is expected to be better than ± 0,05% per annum (0,1% for range 6). Recalibration is straightforward using a set of standards. (See section 7.0)

Temperature Range
Operating: 0 to 40°C
Storage: –20°C to + 70°C

Temperature Coefficient
Less than ± 0,01%/°C over the operating range (± 0,02% for range 6)

Response Time
Automatic Mode: 1 – 4 seconds
Manual Mode: 1 second max.

Input Protection	Protected against all combinations of open and short circuits	
Overload Conditions	Wrong range selected:	19999 flashing on both displays
	Wrong function selected:	–0000 on left display. (This allows non-reactive resistors, ie. those with no C or L components, to be measured either as a resistance or as a conductance.)
		Both displays flash 0000 when the reactive component is greater than about minus 100 digits.
	Dissipation Factor:	For D.F. greater than 1, flashing 1.0000 on right display.
Function Switches	AUTO L/R – series inductance and resistance C/G – parallel capacitance and resistance	
DC Bias Voltage	A d.c. bias voltage, selected by a front panel switch, gives a unidirectional test signal on capacitance/conductance ranges 4, 5 and 6 as required for some types of tantalum electrolytic capacitors. Ranges 4 and 5: 1,5V Range 6: 150 mV.	
Display	Two light emitting diode displays, each with 5 characters. Maximum indication: 19999. Decimal point and unit of measurement displayed. Left display: capacitance or inductance Right display: conductance or resistance. Also dissipation factor.	
Front Panel Electrical Inputs	Two current terminals Two potential terminals One guard terminal All screw terminals with 4 mm sockets	
Rear Panel Electrical Inputs	Range, function and dissipation factor command signals Run/Stop command	
Rear Panel Electrical Outputs	B.C.D. outputs of both displays, over-range and negative measurement (TTL compatible form) Data Ready signal Remote range, function and dissipation factor signals.	
Power Supply	Mains power 200–260V or 100–130V, 50 or 60 Hz. 25 VA (approx)	
Fuse	20 X 5 mm, slow-blow (T) 250 mA, 250 V for 220/240 V supply 500 mA, 250 V for 120/110 V supply	
Dimensions	430 X 195 X 275 mm (17 X 7¾ X 10¾ in)	
Weight	8,1 kg (18 lb)	

4.1 **Universal Component Jig AC5556**

Length of components accepted	5 mm to 95 mm (radial or axial leads)
Residual capacitance	0,05 pF max.
Residual inductance	0,25 μH max.
Residual resistance	0,001 Ω max.
Residual conductance	0,0001 μS max.
Dimensions	160 X 165 X 85 (height) mm
Electrical outputs	3–pin DIN socket connected to internal microswitch. When jig is open, pins 2 and 3 are shorted When jig is closed, pins 1 and 2 are shorted

Length of leads	0,65 m (approx)

4.2 **Lead Set** 6110–176

Residual capacitance	0,02 pF max.
Residual inductance	0,25 μH to 1 μH depending on the position of the leads (see Section 6.2.2)
Residual resistance	0,5 mΩ max.
Residual conductance	0,0001 μS max.
Length of leads	0,65 m (approx)

5.0 OPERATING INSTRUCTIONS

5.1 Preliminary Procedure

5.1.1 Installation

The instrument is normally supplied for an input of 240 V (230–260 V), 50/60 Hz. It may be re-set for 110 V (100–115 V) , 120 V (115–130 V), or 220 V (200–230 V) by adjusting the voltage selector on the rear panel. Ensure that the power is not connected before making adjustments; the voltages are clearly identified.

The mains lead is coded as follows:

BLUE – NEUTRAL
BROWN – LINE
YELLOW/GREEN – EARTH

Before connecting up to the mains supply, ensure that the correct fuse has been inserted. The fuse holder is located in the rear panel.

Fuse Rating: 250 mA for 220/240 V supply
500 mA for 110/120 V supply

5.1.2 Preparation

Switch the power switch to ON and the display will be illuminated. When switched on, the instrument is in the fully automatic mode, and the AUTO RANGE and AUTO FUNCTION lamp indicators are illuminated. No warm-up time is required and there is no setting-up procedure necessary.

5.1.3 Test Jig AC5556

For many applications it is recommended that connections be made through the Test Jig AC5556 accessory unit, which accepts most discrete components.

The jig is connected to the AC5555 by pushing the plug unit into the instrument terminals.

5.1.4 Precautions

Ensure that all capacitors are discharged before connecting them to the AC5555.

5.2 Component Measurement

5.2.1 Component Connection

(a) Connect the Test Jig AC 5556 or other suitable jig. Alternatively, use the special test leads, available as an optional accessory.
(b) Connect the component to the test jig.

5.2.2 Automatic Mode

(a) The instrument is in the automatic mode when it is switched on.
(b) Read off the value from the two displays. The decimal point and correct unit are automatically indicated. (It should be noted that S on the right-hand display represents Siemen, the unit of conductance.)
(c) If it is required to measure the dissipation factor of a component, depress the DISSIPATION FACTOR switch, and the light will be illuminated. The dissipation factor is shown on the right-hand display. If the dissipation factor of the component is greater than 1 the display flashes 1.0000. To cancel the dissipation factor facility, press the switch again.

For an inductor, it may be more convenient to obtain a value for the quality factor, Q. This may be calculated from the measured dissipation factor by the formula:

$$Q = \frac{1}{\tan \delta}$$

$$\text{ie Quality factor} = \frac{1}{\text{Dissipation Factor}}$$

5.2.3 **Manual Mode**

The instrument may be used in the Auto-range mode, in which case the function is selected, or in the completely manual mode when both function and range are selected.

(i) *Auto-range Mode*

(a) If it is not known whether the component is an inductor, capacitor or resistor, first select the AUTO function. The value of the component will be displayed, and either the L/R or C/G lamp indicator will be illuminated. Then press the appropriate function switch.
(b) Continue to make further measurements. The instrument will automatically select the correct range.
(c) Dissipation factor may be measured in the normal way.

(ii) *Manual Mode*

This method of operation is the fastest when measuring a batch of components all of approximately the same value.

(a) First select the AUTO function. The value of the component will be displayed.
(b) Press the range switch whose lamp is illuminated; the instrument is now locked into the correct function and range.
(c) Continue to make further measurements in the normal way.

5.2.4 **Measurement of Electrolytic Capacitors**

This technique is suitable for particular types of tantalum capacitors for which it is important not to apply a reverse bias. For normal electrolytic capacitors the technique may be used but is not absolutely necessary since no noticeable improvment in readings is obtained.

(a) Connect the Test Jig as normal.
(b) Switch on the DC Bias Voltage by means of the switch in the bottom right of the front panel.
(c) Connect the capacitor to the jig with the + side of the capacitor (anode) to the positive side of the supply (left).
(d) The value of the capacitor will be displayed in the normal way.
(e) The d.c. bias voltage only appears at the terminals in the capacitance function on ranges 4, 5 and 6. The magnitude is 1,5 V on ranges 4 and 5, and 150 mV on range 6. This results in a unidirectional signal applied to the capacitor.
(f) The values displayed are the *parallel* capacitance and conductance. See 'Measurement Techniques'. (6.2.5)

5.3 **Systems Use**

A comprehensive set of input and output connections enable the instrument to be used in automatic and semi-automatic systems.

There are three sockets on the rear panel. These provide TTL compatible outputs which will drive one TTL load. The logic levels are standard TTL levels. Suitable plugs are available as optional accessories (See section 3.5). Sockets 2 and 3 have the same lay-out of output connections and are therefore pin compatible, enabling them to be interchanged easily. The only difference is that there is no 'wrong function' connection on socket 3. Socket 4 has both input and output connections. The data output from either socket 2 or 3 may be used in conjunction with a printer, recorder or digital comparator.

Two rack-mounting brackets are available at extra cost as optional accessories. To fit these, first remove the two front screws on each side of the instrument then fix the brackets using the longer screws provided. The feet may be removed in order to slide the instrument into the rack.

5.3.1 **Socket 2**

This socket is mainly concerned with the B.C.D. output of the number on the C/L (left) display. The layout of the pins is as follows:

Pin	Function	
1	5V O/P	
2	O/R	
3	W/F	
4	1	Most significant digit
6	8	
7	4	
8	2	2nd digit
10	1	
12	8	
14	4	
15	2	3rd digit
16	1	
18	8	
20	4	
22	2	4th digit
23	1	
24	8	
26	4	
27	2	Least significant digit
28	1	
29	0V	

Pins 1 and 29 — may be used to power auxiliary equipment. Current limited to 200 mA. (Do not connect to +5 V output on other sockets)

Pin 2 — Over-range. Indicates an over-range measurement.

Pin 3 — Wrong function. Indicates that the wrong function (C/G or L/R) is selected. Corresponds to the minus sign on the front panel display.

Pins 4 – 28 — B.C.D. data output of the number on the C/L (left) display.

5.3.2 **Socket 3**

This socket is identical with socket 2 except that pin 3 (W/F) is not connected. It is mainly concerned with the b.c.d. output of the number on the G/R/DF (right) display. The layout of the pins is as follows:

Pin	Function
1	5V O/P
2	O/R
4–28	As socket 2
29	0V

Pins 1 and 29 — may be used to power auxiliary equipment. Current limited to 200 mA. (Do not connect to +5 V output on other sockets)

Pin 2 — Over-range. Indicates an over-range measurement.

Pins 4 – 28 — B.C.D. data output of the number on the G/R/DF (right) display.

5.3.3 **Socket 4**

The layout of the pins is as follows:

Pin	Function
1	5V
2	C/G FUNCTION EXT. I/P
3	R/S EXT. I/P
4	4 EXT. RANGE I/P
5	D.F. EXT. I/P
6	2 EXT. RANGE I/P
7	D.F. MODE O/P
8	1 EXT. RANGE I/P
10	1 RANGE O/P
12	2 RANGE O/P

14	4 RANGE O/P
15	DATA READY
16	C/G FUNCTION O/P
17	0V

Pins 1 and 17 — may be used to power auxiliary equipment. Current limited to 200 mA. (Do not connect to 5 V outputs on other sockets.)

Pin 2 — Externally commands capacitance (C/G) or inductance (L/R) functions. This command can only be used in REMOTE. C/G is logic 1; L/R is logic 0.

Pins 4, 5, 6 — B.C.D. code of range. Input command. Ranges 0 – 6. This commands REMOTE if the instrument is in the AUTO mode. Automatically goes to logic 111 (NOT REMOTE) with no input.

Pins 10, 12, 14 — B.C.D. output code of range. Ranges 0 – 6.

Pin 5 — Externally commands dissipation factor. Can only be used in REMOTE. DF is logic 1. Not DF is logic 0.

Pin 7 — Output for dissipation factor mode. If D.F. selected, logic 1; if D.F. not selected, logic 0.

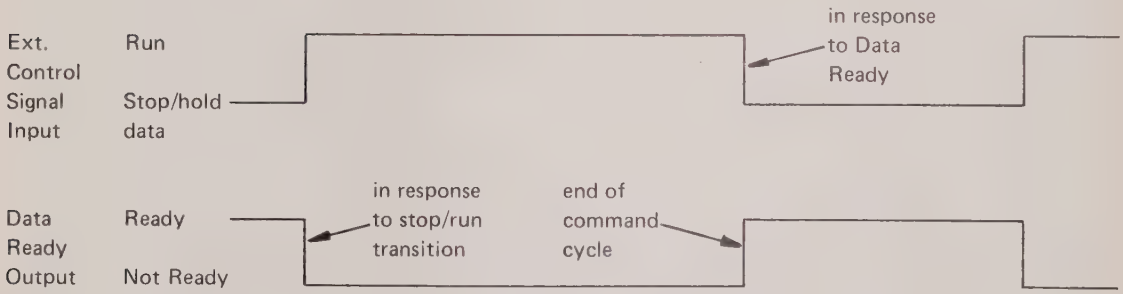
Pin 16 — Output for capacitance (C/G) or inductance (L/R) functions. C/G is logic 1; L/R is logic 0.

Pins 3 and 15 — Run/stop input command, Data Ready output.

These two pins are used with automatic measurement systems.

R/S — The instrument is free-running in logic 1. In logic 0, the reading is held in the display and the measurement process is stopped when the basic measurement cycle of 400 ms is complete. Goes to logic 1 when not connected.

Data Ready — In logic 1, the data is ready to be printed or recorded externally. In logic 0, the data is not ready because a good measurement has not been achieved.



Under normal conditions, the correct range is selected, either remotely or manually. In this case, the component to be measured is connected with the R/S input at logic 0. Either manually or automatically, the R/S input is externally set to logic 1, which commands the measurement of the unknown component. In response to the R/S transition to logic 1, the Data Ready output is internally set to logic 0, indicating that the data output is not a representation of the true value of the component and should not be recorded. The duration of the basic measurement cycle is 400 ms, but in order to ensure that an accurate measurement has been made, a measurement time of 700 ms is allowed. When the measurement time is complete and the correct value of the component displayed, Data Ready is internally set to logic 1. In order that the data is held to enable it to be recorded, R/S should be externally set to logic 0. The instrument will stop at the end of the 400 ms measurement cycle. The component may also be changed for the next measurement.

For the optimum speed of operation, it is necessary to complete the stop/hold phase (R/S I/P logic 0), together with the recording and component changing operations, within 100 ms of the Data Ready transition to logic 1. In this case the instrument will not stop and will be ready to measure the next component at the beginning of the following basic measurement cycle. The optimum speed of operation is thus one component for each 800 ms.

If the instrument is not in the correct range and AUTO is selected, an additional measurement cycle is completed for each range passed through to reach the correct range.

5.3.4 **Remote Function**

Pins 4, 6 and 8 on socket 4 are the binary coded input connections for the range. Normally these inputs are all in the 1 state, which means that the instrument is set for internal operation. However, if these inputs are set externally to any code other than 111 the instrument is put into REMOTE, and the code selects the ranges 0–6. In the REMOTE function, it is necessary to select, via pins 2 and 5 of socket 4, the correct function and dissipation factor state. The Remote function is associated with the AUTO function. Thus, if the operator wishes to take the instrument out of the Remote function, he has only to push one of the range buttons on the front panel. To take the instrument back into Remote, the AUTO button should be depressed, and the REMOTE indicator lamp will be illuminated.

With no connections to socket 4 the instrument functions normally.

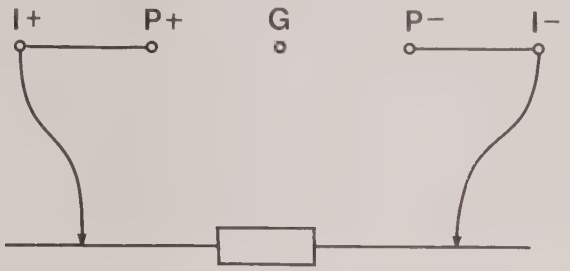
6.0 MEASUREMENT TECHNIQUES

For the majority of measurements using the AC5555 Component Analyser, no special measurement techniques are required, particularly if the test jig AC5556 is used. However at the extremes of the measurement range certain precautions are advisable in order to avoid errors.

6.1 Connection Methods

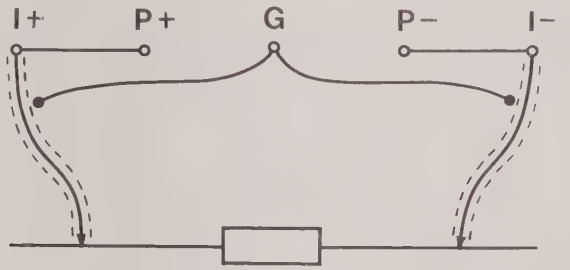
First, consider the four different ways in which connections may be made to a component.

6.1.1 Two Terminal



This is the simplest method of measurement and may be used on ranges 2, 3 and 4 without introducing significant errors. The two outside pairs of terminals are shorted together and connections made to the component using two ordinary leads. This method is merely a quick and convenient method for measuring a component, with no particular advantages, but is adequate in mid-range for normal discrete components.

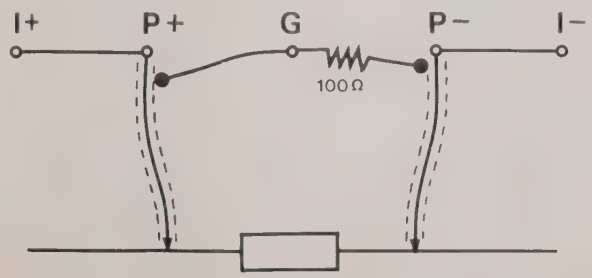
6.1.2 Three Terminal



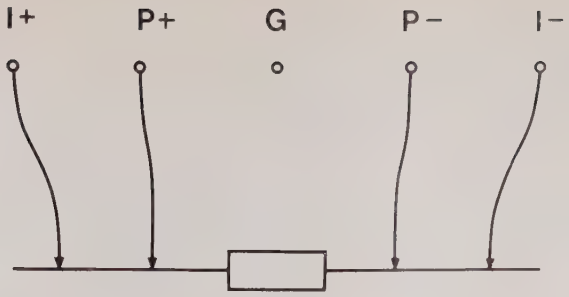
This method of connecting to the component is necessary for the high impedance ranges 0 and 1. On these ranges capacitance between the leads may cause significant errors. In this case it is necessary to use screened leads and to connect the screens to the central guard terminal G. It is recommended that low capacitance cable is used. This method should be used when measuring high value inductors as well as low value capacitors. It can also be used for the measurement of networks, in which the unwanted impedances can be joined together and connected to the guard without introducing errors. In the C/G mode, the minimum impedance from the I+ terminal to guard is 200 Ω or 1 μF on all ranges. In the L/R mode, the maximum impedance from the I+ terminal to guard is dependent on the range as follows:

Range	Max. Impedance
0	800 pF or 300 kΩ
1	1,5 nF or 200 kΩ
2	15 nF or 20 kΩ
3, 4, 5, 6	1 μF or 200 Ω

The impedance from the I- or P- terminal to guard should be kept as small as possible. On range 0 it is limited to 250 pF and on all other ranges to 500 pF. For some applications it may be necessary to use long leads with a capacitance exceeding 250 pF between the I- or P- terminal and the guard terminal. In this case it is recommended that the following connection system be used:



6.1.3 Four Terminal

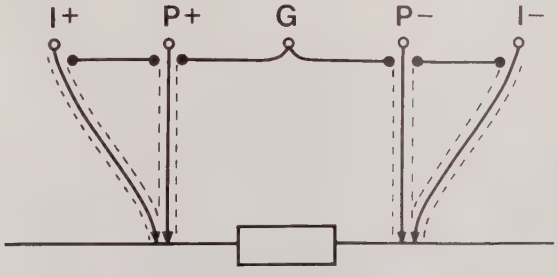


This method of connecting to the component is suitable for the low impedance ranges 5 and 6. In this case the impedance of the leads may be significant compared with the impedance to be measured. To overcome this problem, the current is passed through the component via the two terminals I+ and I−. The potential difference across the component is measured via the terminals P+ and P−. In this way the impedance of the current carrying leads is not measured. In the case of very low impedance measurements, errors may be experienced if the connection impedance between the I terminal and the P connection is large. The potential drop across this connection impendance should be limited to 0,5 V. Thus, for each lead, the maximum impedance for the different ranges is:

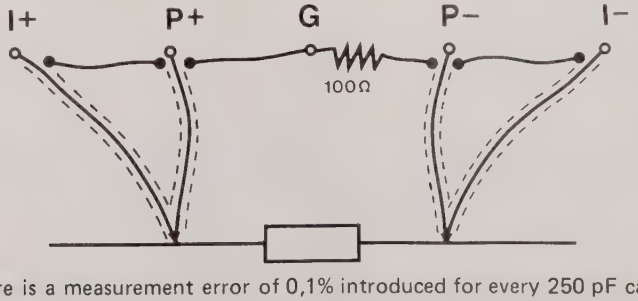
Range	Connection Impedance
0, 1, 2, 3	200 Ω
4	20 Ω
5, 6	2 Ω

Internally there are parallel back-to-back diodes and a 1 kΩ resistor connected between the current and potential terminals.

6.1.4 Five Terminal



This is a general method of connection which incorporates both the three and four terminal methods. It is thus suitable for all measurement ranges. All leads used are screened and the screens connected to the guard terminal. This is the arrangement used in the Test Jig AC5556 and in the special test leads. Thus by using either of these connection systems many of the possible errors are eliminated. For some applications it may be necessary to use long leads with a capacitance exceeding 250 pF between the I− or P− terminal and the guard terminal. In this case it is recommended that low capacitance cable be used and the following system implemented:



On range 0 only, there is a measurement error of 0,1% introduced for every 250 pF capacitance between P− and I−, and the guard terminal.

6.2 Measurement Problems

Assuming that the appropriate connection system is used, there are some additional problems which may be encountered when measuring particular types of component.

6.2.1 Measurement of High Impedance

When measuring low value capacitors and high value inductors, it is important to take particular care to avoid stray capacitance across the component. Ensure that the component leads are well separated whenever possible. However, if a high value resistor is screened in an attempt to reduce the capacitance between the ends, this may inadvertantly lead to further problems since the resistor effectively changes from one having parallel capacitance to one having series inductance.

6.2.2 Measurement of Low Impedances

The alternating current passing through the current leads can set up a magnetic field in the potential leads, producing a mutual inductance effect. This can cause errors when measuring low value inductors and high value capacitors. To minimise these errors take care to separate the potential and current leads.

The optimum conditions are achieved by pairing together the two current leads, thus reducing the magnetic field, and pairing together the potential leads. The worst case will be achieved by taking the I+ and P+ leads together and the I− and P− together, which may be the natural arrangement considering the layout of the connections. A reasonable compromise situation is to take all four leads together to the component, thus considerably reducing the overall effect.

6.2.3 Measurement of Inductors

Mains pick-up may cause difficulties in inductor measurements, exhibiting itself in a slow cyclic variation in the last digits of the reading. It is thus advisable to keep the inductor away from mains or other electrical interference, including the instrument itself. A considerable improvement may be effected by rotating the axis of the inductor.

A different problem may be experienced when measuring air-cored inductors. Errors may be caused by neighbouring metallic masses, particularly steel which is likely to cause a positive error. The inductor should therefore be separated from any metal objects, including benches, pipes etc. and the instrument itself.

6.2.4 Dissipation Factor Measurements

The dissipation factor as displayed on the right-hand digital display is calculated from the formula:

$$\text{D.F.} = \tan\delta = \frac{R}{\omega L} \text{ or } \frac{G}{\omega C}$$

$$= \frac{\text{reading on right display}}{\omega \times \text{reading on left display}}$$

The error in the dissipation factor measurement thus depends on the error of both the right hand and left hand displays. The error expressed as a percentage for either display increases as the reading decreases as a result of the unavoidable ±1 digit uncertainty. Thus if either or both of the readings is small, the error in the dissipation factor is significant. This is of particular relevance if C or L is small, as this is the divisor in the formula. The resolution in the calculation is thus decreased to such an extent that the last figure in the dissipation factor becomes meaningless; in some cases the last two or even three figures are meaningless. The instrument has been designed so that these meaningless digits are displayed as zeroes. The situation can therefore arise in which the last one or more digits are displayed as 0 and the previous digit may be changing numbers. The appearance of this display may seem unfamiliar, but there is no fault in the equipment. In some cases the last significant digit may change by more than one figure, so, for example, the third digit may be changing from 5 to 8. This is quite normal and actually gives an indication of the accuracy of the dissipation factor measurement being made.

eg. 0.1500 alternating with 0.1800 indicates a dissipation factor of between 0.15 and 0.18 measured with an accuracy of approximately 20%.

It should be noted that the dissipation factor is calculated as if at a precise frequency of 1 kHz. In other words, the dissipation factor is not calculated from the actual measurement frequency, which could be 1 kHz ± 0,5%.

6.2.5 **Measurement of Electrolytic Capacitors**

When measuring capacitors the parameters measured are the capacitance and *parallel* conductance. For electrolytic capacitors the capacitance normally quoted is the *series* capacitance, assuming that the resistance and capacitance are in series. Now the two capacitances may not have the same value if the dissipation factor is high. It is possible to calculate the series capacitance C_s from the parallel capacitance C_p from the formula:

$$C_s = C_p (1 + D^2)$$

where D is the dissipation factor.

6.2.6 **Measurement of AC Resistance**

For a normal resistive element the d.c. and 1 kHz resistance will be effectively the same. However, for some systems there may be losses associated with a.c. which do not occur in d.c. measurements, thus producing a different reading. An example of this is the winding resistance of a transformer; when measuring this on an a.c. instrument such as the AC5555, core losses and capacitance between the windings produce a different reading. Thus it should not be thought unusual in such cases to find a difference between a measurement made by a d.c. instrument and the measurement made on an a.c. instrument such as the AC5555.

6.2.7 **Potential Difference between Guard Terminal and Chassis**

The d.c. potential difference between the Guard or other measurement terminals and the instrument chassis (mains earth) must be kept below 50 V. The a.c. potential difference between Guard and chassis should be kept small, otherwise a noisy measurement will be displayed.

7.0 TECHNICAL DESCRIPTION

7.1 Introduction

The Automatic Component Analyser AC5555 utilises the ratio measuring capability of the 'Dual Slope' analogue to digital conversion method to measure the ratio of voltage to current in the unknown component (impedance) and the inverse ratio of current to voltage (admittance).

Phase sensitive detector techniques are used to separate the real and imaginary components. In this way the inductance and resistance, from the impedance measurement, or the capacitance and conductance, from the admittance, are displayed separately.

7.2 General Circuit Description

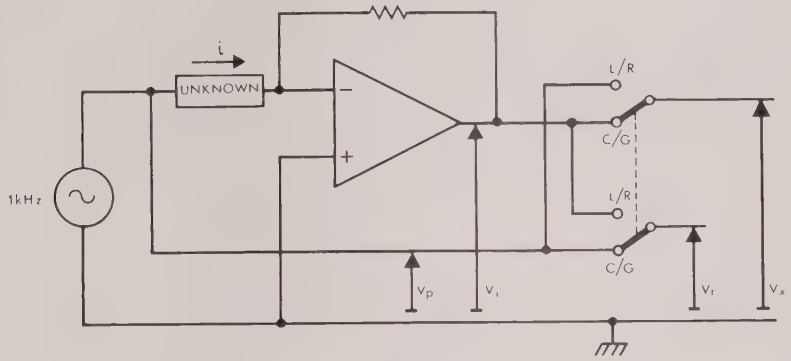
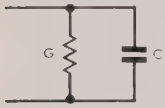


Fig. 1

The impedance of a device is defined as the ratio of the potential difference across the device, to the current through it. In Fig. 1, V_p is the potential difference across the unknown component and V_i is the current through it multiplied by a scaling resistance R_s. If R_s is known, the ratio of V_p to V_i is a measure of the impedance of the component, and the ratio of V_i to V_p is the admittance. By effectively altering the value of R_s between 1 Ω and 1 MΩ, the different ranges can be obtained.

Capacitance and parallel conductance are measured as an admittance, while inductance and series resistance are measured as an impedance.



$$\text{admittance} = j\omega C + G$$

$$\text{impedance} = j\omega L + R$$

The ratio of V_x to the reference voltage V_r measures impedance or admittance, depending on the position of the switch, as shown in Fig. 1. This ratio is measured using the dual slope technique.

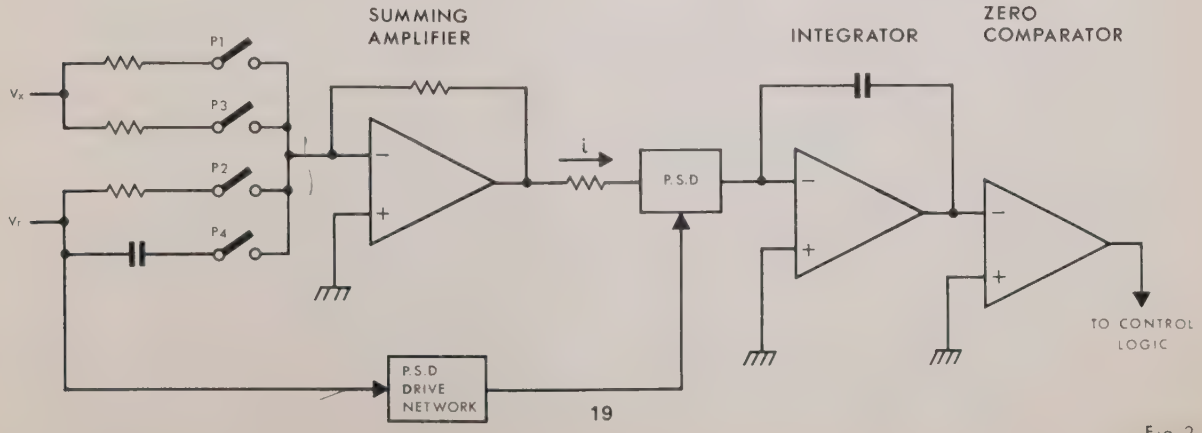


Fig. 2

The measurement cycle has four main phases; the first two are dedicated to the measurement of the real component and the second two to the measurement of the reactive component. In the first and third phase V_x is connected to the summing amplifier, while in the second and fourth, V_r is connected. The difference between the measurements is that the first measures the component of V_x in phase with V_r and the second measures the component of V_x at 90° to V_r.

Phase 1

The switch P_1 (see Fig. 2) is closed, causing a current proportional to V_x to flow into the phase sensitive detector (P.S.D.). The latter full-wave rectifies the component of its input current that is in phase with its drive signal. Hence a direct current flows into the integrator causing a positive ramp at its output. Out of phase signals produce no net direct current, thus separating the resistive from the reactive part of the impedance of the component under test. The integrator ramps up for a fixed time T, which is the time it takes for a counter to cycle from 00000 up to 19999.

Phase 2

Switch P_1 is opened and P_2 closed, causing the integrator output to ramp down with a slope proportional to V_r. When the integrator output crosses zero the number in the counter is a measure of the ratio of the in-phase part of V_x, to V_r. This number is then stored and displayed as the resistance or conductance. Switch P_2 is opened and the integrator set to zero in a hold phase, P_H, which lasts until the counters have finished counting up to 19999.

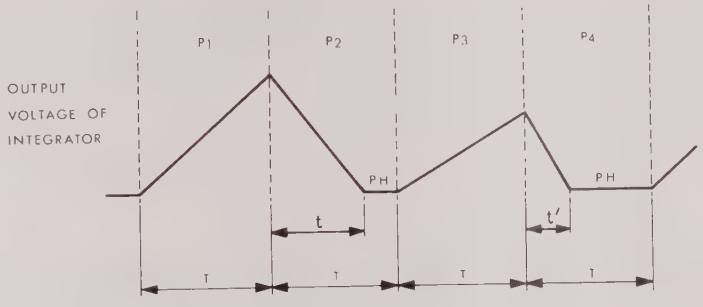


Fig. 3

Phase 3

Switch P_3 is closed and the P.S.D. full-wave rectifies the component of its input current that is 90° out of phase with V_r. This causes a positive ramp on the integrator output for a fixed time T. The slope is proportional to the out-of-phase component of V_x.

Phase 4

Switch P_3 is opened and P_4 closed. The integrator output now ramps down to zero with a slope proportional to V_r. At the zero crossing the number in the counter is stored and displayed, thus measuring the capacitance or inductance of the unknown. As in Phase 2, the integrator goes into a hold phase, P_H, until the counter reaches 19999.

Third Ramp

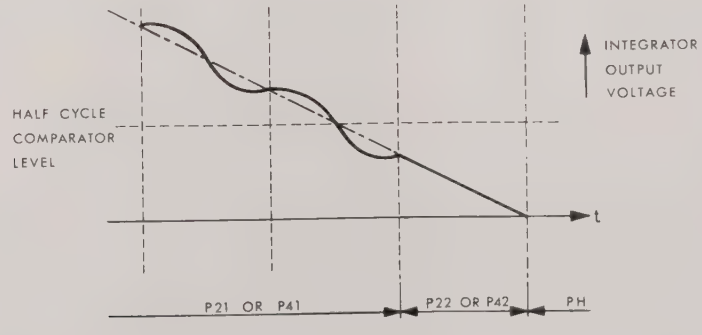


Fig. 4

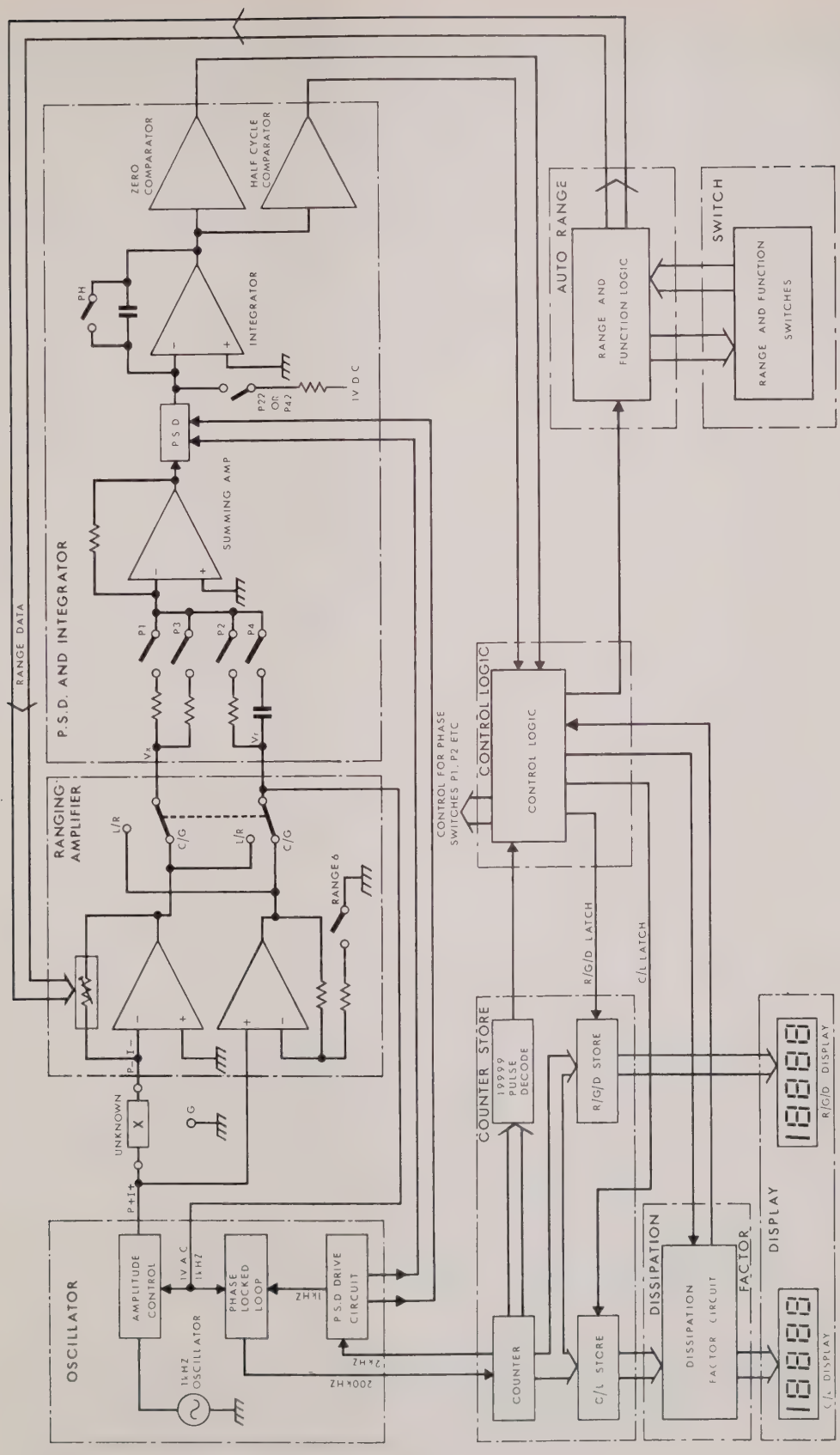

RANGE DATA
P.S.D. AND INTEGRATOR
ZERO COMPARATOR
HALF CYCLE COMPARATOR
PH
INTEGRATOR
P22 OR P42
1V D C
P S D
SUMMING AMP
P1
P3
P2
P4
RANGING AMPLIFIER
L/R
C/G
RANGE 6
CONTROL FOR PHASE SWITCHES P1, P2 ETC
CONTROL LOGIC
AUTO RANGE
RANGE AND FUNCTION LOGIC
SWITCH
RANGE AND FUNCTION SWITCHES
R/G/D LATCH
C/L LATCH
UNKNOWN
X
G
COUNTER STORE
19999 PULSE DECODE
R/G/D STORE
R/G/D DISPLAY
OSCILLATOR
AMPLITUDE CONTROL
1V A C 1kHZ
PHASE LOCKED LOOP
1kHZ
P.S.D DRIVE CIRCUIT
1kHZ OSCILLATOR
2kHZ
200kHZ
COUNTER
C/L STORE
DISSIPATION
DISSIPATION FACTOR CIRCUIT
FACTOR
DISPLAY
C/L DISPLAY

Fig. 5

As the up and down ramps are produced by a rectified sine-wave, they are non-linear. This is of no consequence when a whole number of half cycles are integrated, so the time T must be a fixed number of half cycles. The counter clock frequency is hence locked to the measurement signal frequency. The duration of the down ramps (t and t' in Fig. 3) are dependant on the unknown and it is unlikely that the zero crossing will occur at a whole number of half cycles. Because of this there is a second comparator which detects the point at which the down ramp is approximately one half cycle away from the zero crossing. Then at the completion of the next half cycle a fixed direct current is used to produce the last part of the down ramp, whose slope is equal to the average slope of the remainder of the down ramp. The down ramp slope must therefore be fixed, meaning that V_r must be fixed. This is achieved by means of an amplitude controller circuit which sets V_r to a fixed value of 1 V r.m.s.

7.3 **Ranging Amplifier** Refer to circuit diagram, page 75.

The purpose of this board is to generate the voltages V_r and V_x from the current through the unknown and the voltage across it.

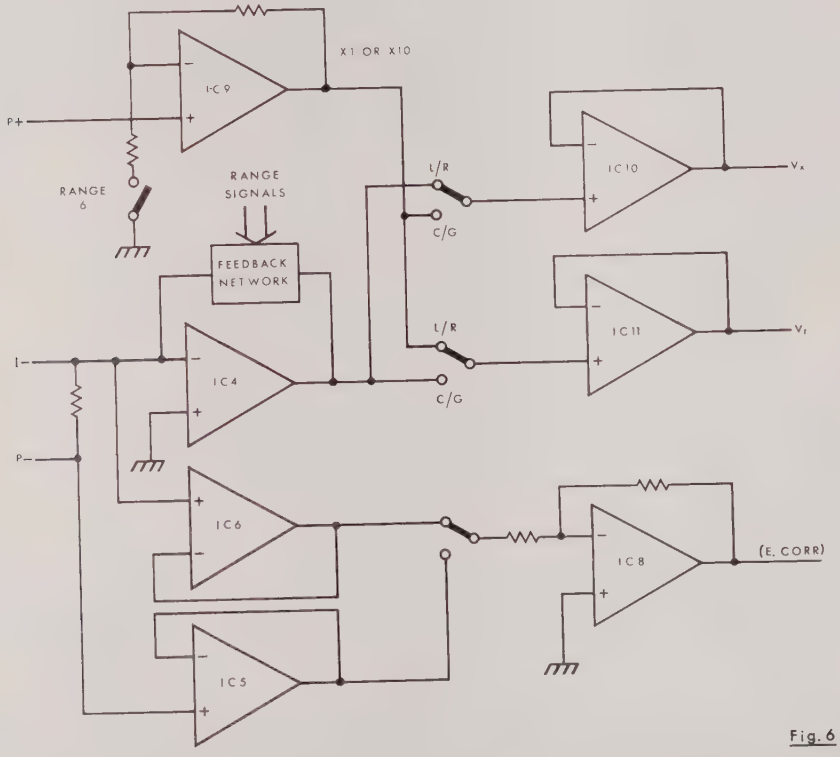


Fig. 6

The current through the unknown component flows into the virtual earth of IC4 and through a feedback resistor, to produce a voltage proportional to this current. To handle the high currents, the integrated circuit IC4 incorporates a power buffer stage on its output (TR20 to TR24 and associated components). The feedback resistors are interchanged using switching field effect transistors. For the low value resistors the current is fed through one f.e.t. and the potential at the resistor is measured through another f.e.t. having a high impedance load. This eliminates the effect of the resistance of the f.e.t.'s TR12 to TR18.

For range 6 an effective feedback resistance of 1 Ω is required. This is implemented by using a feedback resistor of 10 Ω as on range 5 and multiplying by 10 the measured potential difference across the unknown using IC9. The 100 kΩ and 1 MΩ feedback resistors are effected using T-networks (R8 to R13 and R20, R21). All switching f.e.t.'s are driven by CMOS logic packs, either directly or via transistors (IC1 to IC3, TR1 to TR5).

As IC4 has a limited gain there is an error voltage at its virtual earth, which is subtracted during the appropriate phase at the input of the summing amplifier. This error voltage is buffered by IC6. The tail of the T-networks used for ranges 0 and 1 are tied to the output of this operational amplifier. To eliminate loading effects IC6 has a power output stage to reduce its output impedance (TR33, TR34 and associated circuitry).

The potential on the oscillator side of the unknown is buffered by IC9, and on range 6 this operational amplifier is arranged to have a gain of 10 (TR43 to 48, R57 to 64). The potential at the P– terminal is buffered by IC5 and then subtracted from the output of IC9 at the input of the summing amplifier (Phase Sensitive Detector Board) during the appropriate phase. This error signal and the error signal buffered by IC6 are switched by TR35 and TR36 to the input of IC8, which is a x10 inverting amplifier. The output of IC8 is then connected to the summing amplifier on the Phase Sensitive Detector Board.

The function switching is effected by the switching f.e.t.'s TR28, TR29, TR41 and TR42. The outputs of these f.e.t.'s are then buffered by TR10 and IC11.

7.4 **Phase Sensitive Detector (P.S.D.) Board** Refer to Circuit Diagram, page 77.

The function of this board is to split V_x into its two phases nd convert the ratios of these to V_r into two time ratios.

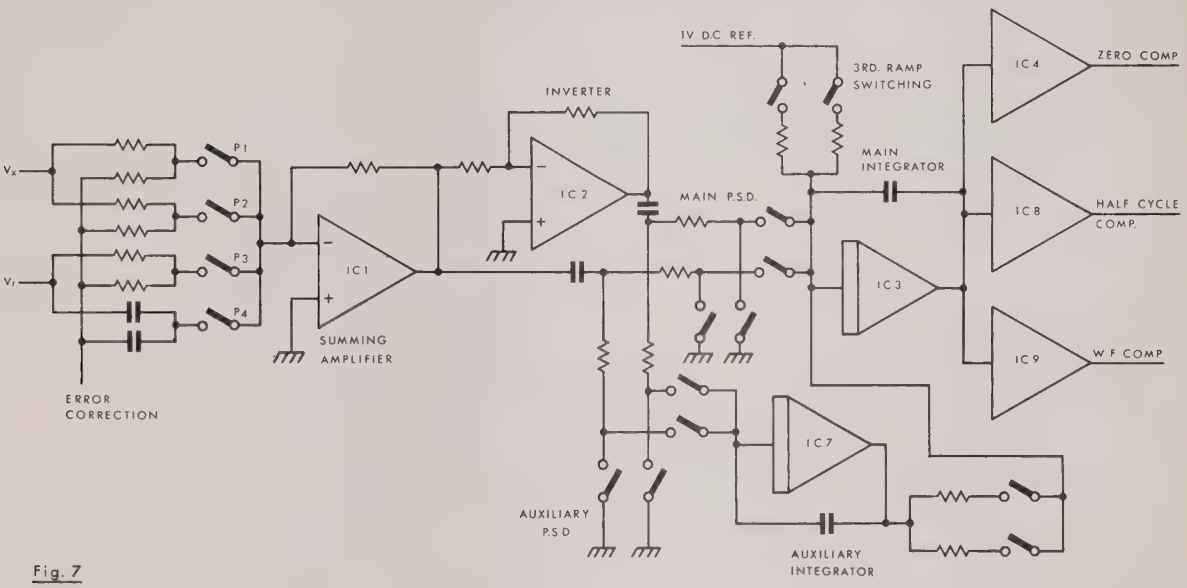


Fig. 7

Summing Amplifier

The signals V_x and V_r from the ranging amplifier are a.c. coupled (C1 to C3) to the components at the input of IC1 (R2, 3, 6, 7, 11, C4, L1). The other ends of these components are switched to the virtual earth of IC1 or ground, depending on the measurement phase of the instrument (TR4 to TR8, TR37 to TR39). The coupling capacitors C1 to C3 are discharged into a d.c. load resistance (TR1 to TR3, R1, R5 and R9). The error signal from IC8 on the Ranging Amplifier Board, which corrects V_x and V_r is connected to the input of IC1 via the switches TR4 to TR8 and TR37 to TR39, and through the components R4, R8, R10, R12, and C5, which have an impedance ten times that of the main signal components.

Phase Sensitive Detector

The output of IC1 is inverted by IC2, then both outputs are a.c. coupled to the P.S.D. by capacitors C9 and C10. These are discharged during P_H by TR22, TR23, TR36, and associated components.

The P.S.D. consists of a pair of series-shunt f.e.t. switches (TR9 to TR12), driven by signals from the oscillator board. The output current from the P.S.D. flows into the virtual earth of the main integrator IC3.

Main Integrator

During the hold phase, switches TR19 to TR21 are closed and TR18 open. This stores the offset voltage of IC3 on C11, and discharges C12. In the measurement phases, TR19 to TR21 are open and TR18 closed. Thus the input of the integrator is accurately at 0 V. The third ramp (P_{22} and P_{42}) currents are switched through R20 to R23 by TR14 to TR17, from the 1 V d.c. reference. These f.e.t. switches are driven by IC11. Zero adjustment for the resistive measurement is achieved by TR13, R49 to R53, and R56.

Auxiliary Integrator and Phase Sensitive Detector

Delays around the system necessitate the inclusion of a phase error correction circuit. During phases P_{21} and P_{41} the signal proportional to V_r should be in phase with the main P.S.D. drive signal. During these phases an auxiliary P.S.D. (TR24 to TR27) is driven with a signal exactly 90° out of phase with that of the main P.S.D. The input of this auxiliary P.S.D. is the same as that of the main P.S.D. Hence its d.c. output current is proportional to the delay of the system. This current is then integrated during P_{21} or P_{41} by the auxiliary integrator (IC7, TR28 to TR33). This error signal is then subtracted from the main integrator during phases P_1 and P_3 via R34 to R37 and TR34, TR35.

Comparators

To the output of the main integrator (IC3) are connected three comparators. All three have an output that switches between 0 V and - 10 V. IC4 detects the zero crossings; hence the voltage offset adjustment (R26) adjusts the zero of the measurements. IC8 detects when the P_2 and P_4 down ramps of the main integrator are one half cycle away from the zero crossing. IC9 detects whether, at the end of the P_3 phase, the main integrator output is more than approximately 100 digits negative, indicating a wrong function measuring mode.

7.5 **Oscillator** Refer to Circuit Diagram, page 63.

The function of this board is to provide the measurement signal, control the amplitude of V_r to 1 V r.m.s., and limit V_x in overload conditions. The P.S.D.'s drive signals are also generated on this board.

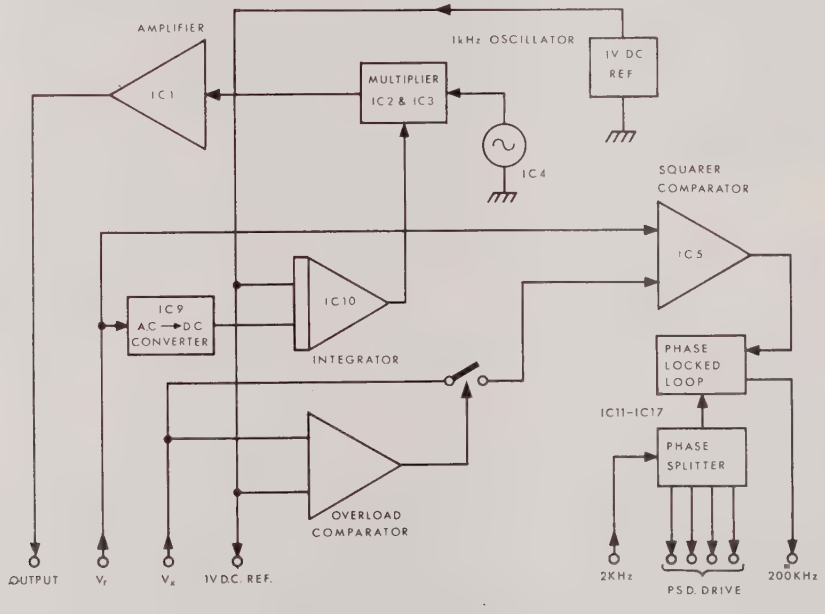


Fig. 8

1V d.c. reference

A stable voltage reference is produced across a precision zener diode D6. This is voltage divided by R30 to R32, and R31 is adjusted to give a 1 V d.c. output.

Oscillator

The oscillator is a Wein bridge network (R22 to R24, C13, C14) around an operational amplifier IC4. The amplitude is controlled by back-to-back diodes in the feedback network (D4, D5, R25 to R28, C15). The output is low-pass filtered (R21, C12) then connected to the amplitude controller.

Amplitude Controller

The amplitude controller consists of a log. and an antilog. amplifier. The log. characteristic is achieved by the base-emitter characteristic of TR7 in the feedback of IC3, d.c. biased by R18. The d.c. control signal is connected to the base of TR7 whose output is then anti-logged by TR6 and IC2.

The d.c. control signal is generated from V_r via an a.c. to d.c. converter and integrator. The 1 V r.m.s. signal V_r is full-wave rectified by a precision rectifier (IC9 and associated components.) This causes a current to flow into the virtual earth of the integrator IC10. An opposing current flows into the virtual earth from the 1 V reference via R75 and R76. When these currents are equal, V_r is set to 1 V r.m.s. and the output of the integrator is stable at the required control voltage for the log. amplifier to which it is connected.

Output Stage

The output of IC2 is a.c. coupled to a power output stage consisting of IC1 and a buffer amplifier (TR1 to TR5 and associated components). The output of the buffer is a.c. coupled to a switching network. This switches resistors in series with the output of the buffer to the I+ terminal on inductance ranges. The switching f.e.t.'s (TR8 to TR11) are driven by transistors 21 to 23, and IC6 and IC7. The d.c. bias is switched by TR13, TR15 to TR19 and associated components. On inductance ranges d.c. feed-back from the ranging amplifier is switched by TR12 and associated components.

Overload Control

In overload conditions, V_x exceed the maximum voltage that can be measured. The amplitude of V_r is reduced to maintain V_x at an acceptable level of about 2,5 V r.m.s. This is achieved by a discrete comparator (TR24, TR25 and associated components). V_x is voltage divided, and when it exceeds the 1 V reference the comparator switches

(a) a current into the amplitude controller to reduce the amplitude of V_r and

(b) a signal to the non-inverting input of the squarer proportional to V_x; thus if V_r is reduced to zero the squarer still has an input signal to enable it to operate. The switch is a CMOS integrated circuit (IC8).

Squarer

The squarer is an integrated circuit comparator (IC5) which converts the signal V_r connected to its inverting input, to a square wave of amplitude 0 V to - 10 V. Under extreme overload, V_r is effectively removed as a result of the control of V_x. Under these conditions the squarer is driven by a signal from the overload control circuit, proportional to V_x. The phase shift between the input and output is controlled by R35 and associated components.

Phase Sensitive Detector Drive

The output of the squarer is connected to an anti-bounce circuit (IC12, C41, C42, R93, R94). The output of this circuit is a.c. coupled to a phase comparator input of the phase lock loop. This phase lock loop (IC11 and associated components) effectively multiplies the input frequency to 200 kHz, which provides the clock for the main counters on the counter/store board. This 200 kHz frequency is divided down by the counters on the counter/store board to produce two 2 kHz signals 180° out of phase. These signals are divided again by IC14 to produce four 1 kHz square waves, accurately at 90° to each other. The 0° phase square wave is connected to the second phase comparator input of the phase lock loop, thus phase locking it to the oscillator frequency. The four 1 kHz square waves are switched by IC15 to IC17 to produce the P.S.D. drives.

If the phase lock loop is out of lock a logic 0 (- 10 V) is present on the out-of-lock (OOL) output of IC13, pin 3.

7.6 **Counter/Store Board** Refer to Circuit Diagram, page 67.

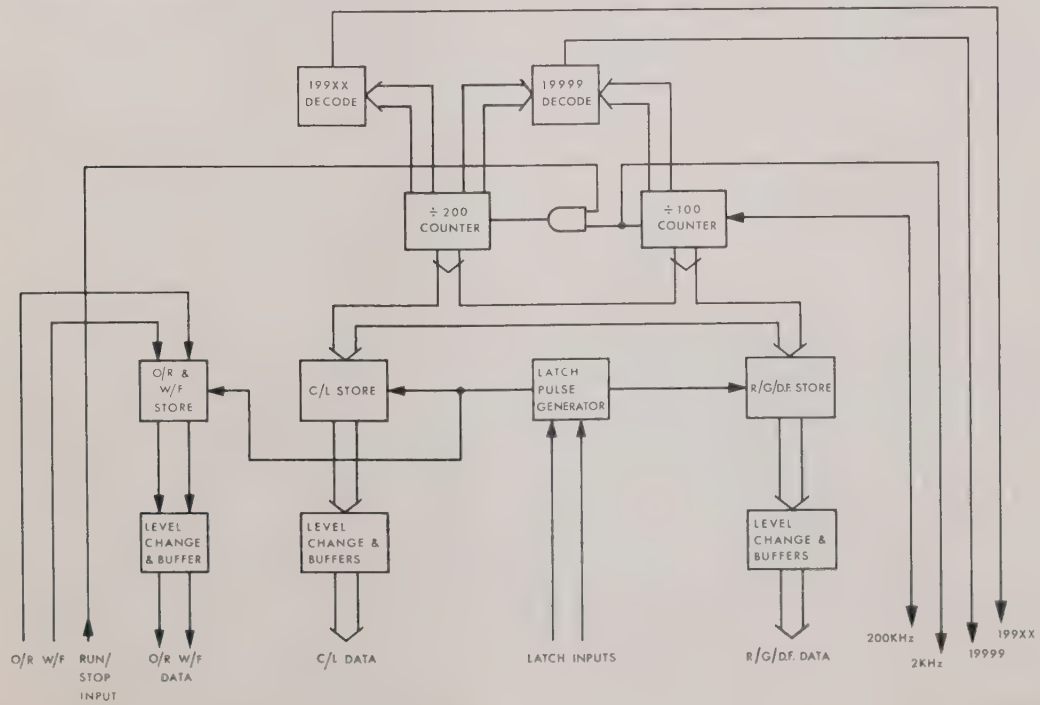


Fig. 9

This board houses the main counter (IC17, 22, 25, 27, and half of IC15 (pins 1 to 7) clocked by the 200kHz signal from the phase lock loop on the oscillator board. The B.C.D. outputs are connected to two stores, one storing the B.C.D. data for the Capacitance/Inductance display, (IC4, 6, 11, 13, 16 (pins 1 to 7)), and the other the data for the Resistance/Conductance/Dissipation Factor display (IC18, 23, 26, 28, 16 (pins 9 to 15)). When a C/L or R/G/D latching signal arrives from the control logic board, this triggers the latch pulse generator circuit (IC30) which produces a narrow pulse synchronous with the 200 kHz clock. At the instant of the trailing edge of this pulse, the B.C.D. number in the counter is latched into the appropriate store. Simultaneously over-range and wrong function information is latched into stores IC3 and IC15. (This is a dual flip-flop; one half uses pins 1 to 7, the other half pins 9 to 15.) The counters and stores operate on 0 V to −10 V logic levels. Hence the store outputs must be level changed to make them T.T.L. compatible. This is achieved by resistors R7 to R79 and the outputs are then buffered by IC5, 7, 14, 19, 24 and 29.

Four numbers are decoded from the counters:

(i) 19999 (IC25 and IC27) which clocks the main phase generators on the control logic board
(ii) 199XX which provides a clamp pulse for the auxiliary integrator on the P.S.D. board (IC7)
(iii) and (iv) The 4 and the 9 decoded from IC25. These are two 2 kHz signals required to drive the phase lock loop on the oscillator board.

The Run/Stop input is first level changed from 0 to 5V, to 0 to −10 V. When the signal is a logic 0, it is used to suppress latching pulses from IC30 and stops the divide-by-200 (IC15, 17, 22) part of the counter when it reaches 199 in phase P_4. This stops the measurement sequence, but the divide-by-100 (IC25 and IC27) is still running, so the 2 kHz signals are still decoded to keep the phase lock loop in lock.

7.7 **Display Board** Refer to Circuit Diagram, page 69.
This board picks up the B.C.D. data output from the counter/store board and uses two 4½ digit, 7 segment displays and a pair of anunciators to present the information.

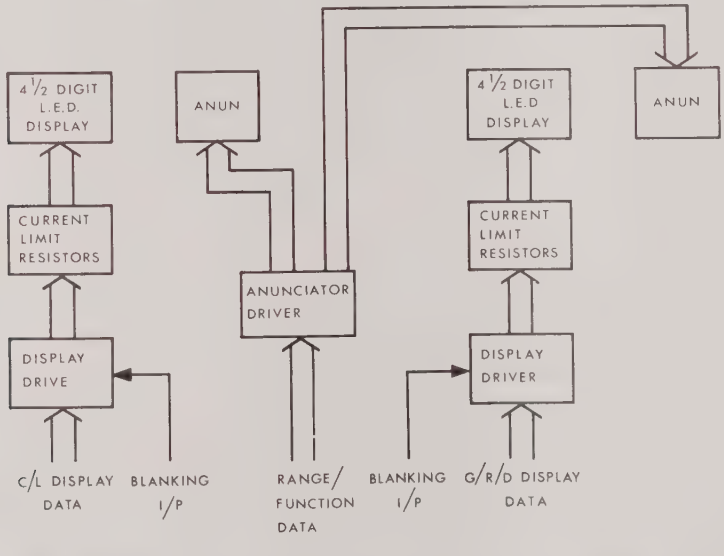


Fig. 10

The B.C.D. data is decoded into signals suitable to drive the l.e.d. 7-segment displays by integrated circuits 1 to 4 and 7 to 10. The display driving current is set by R1 to R3, R5 to R35 and R44 to R78. The most significant digits (1's) and minus sign display are driven by TR1, TR2 and TR16. The units are displayed on a pair of anunciators. These are 12-filament lamps driven in a matrix form by transistors TR3 to TR13 and TR18 to TR22. The base driver for these transistors and the signals for the decimal points are decoded from the range codes, function and dissipation factor by two programmable read only memory integrated circuits (IC5 and IC6).

To enable the display to be flashed during O/R and W/F, it is necessary to blank the displays. The blanking inputs on IC1 to IC4 and IC7 to IC10 are used to blank the 7-segment displays, and D1 to D4 blank the 1's. These inputs are buffered by TR14 and TR15 and their associated circuitry. The blanking signals are generated on the Control Logic Board.

7.8 **Control Logic** Refer to Circuit Diagram page 79.

The function of this board is to generate the measurement phase signals (P_1, P_{21}, P_{22}, P_H, P_3, etc.) which control the measurement cycle. In addition, information from the comparators is turned into pulses to transfer the numbers in the main counters to the store to be displayed. Also the O/R and display blanking signals are produced.

Main Phase Generation

The main phases P_1, P_2, P_3, P_4 are generated by a pair of J.K. flip-flops connected as a parallel clocked counter (IC11) with a binary sequence of: 00, 11, 10, 01, 00, etc. This output is decoded into the main phases by IC12. The flip-flops are clocked on the trailing edge of the decoded 19999 pulse from the counter/store board, ie, the 19999 to 00000 transition of the main counters. In over-range conditions an extra cycle is required by the analogue circuitry. To facilitate this, the 19999 pulse is suppressed by IC10 until the main integrator output has crossed zero.

Sub-Phases

The phases P_2 and P_4 are subdivided into: P_{21} or P_{41}, P_{22} or P_{42}, and P_H. If the half cycle comparator output is at logic 0 (−10V), indicating a measurement of over about 150 digits, the P_2 or P_4 phase starts with P_{21} or P_{41}. In these conditions the Q outputs of a dual J.K. flip-flop (IC19 pins 1 to 7 and 8 to 15) will be at 0 and 1 respectively. From these outputs the sub-phase signal P_{21} or P_{41} is produced via IC16 and IC13. This phase continues until the half cycle comparator output is at a logic 1, which places a signal on the J.K. inputs of IC19 (pins 9 to 15), so that on the arrival of the clocking pulse it will change state to a logic 0. The 2 kHz (9) clock signal from the counter store board clocks the flip-flop at the end of the next complete half cycle into the next phase P_{22} or P_{42}. The output of the flip-flop (IC 19 pin 15) is gated with P_2, P_4 and over-range (IC17 and IC18) to produce the third ramp switching signals Y_1 and Y_2. When the main integrator output crosses zero, the zero comparator output changes state to a logic 1 (0V). This sets the output of a flip-flop (IC19 pin 1) to a 1, cancelling P_{22} or P_{42}, and the instrument is now in the clamp phase P_H, in which it remains until the next main phase.

If the half cycle comparator output is a logic 1 and the zero comparator output a logic 0 at the start of P_2 or P_4, the phases start with P_{22} or P_{42} then go into P_H as above. If both comparators' outputs are at a logic 1, the phase will be entirely P_H. If this occurs in P_3 it indicates that the imaginary component of the measurement is negative. This information is clocked into a J.K. flip-flop (IC15 pin 1) and is used to display the negative sign on the C/L display.

Over-range

A measurement is defined as over-range if, on the arrival of 19999 at the end of phases P_2 or P_4 (which should clock it into the next phase) the instrument is still in the phases P_{21}, P_{22}, P_{41} or P_{42}. If the phase lock loop is Out of Lock the OOL signal from the oscillator board also commands an over-range. This definition is logically implemented by IC6, 7 and 9, which produce a pulse that sets a J.K. flip-flop (IC8 pins 1 to 7) output to logic 1. The arrival of the over-range signal suppresses the 19999 pulse that clocks the main phase generation flip-flops. It is also used in the latch pulse circuit to latch 19999 into the displays, and to switch the Y_1 and Y_2 signals to produce a fast down ramp on the main integrator for the rest of that measurement cycle. Over-range is cancelled by resetting the flip-flop (IC8 pins 1 to 7) with a pulse at the end of the P_1 phase (19999 and P_1).

Wrong Function

If the output of the main integrator is very negative, ie there is a logic 1 on the wrong function comparator output at the end of P_3, this information is clocked into a J.K. flip-flop (IC8 pins 9 to 15) and used to display a flashing 0000. This signal is cancelled by resetting the flip-flop at the end of P_1.

Latch Pulse Generation and Display Blanking

Under normal measurement conditions (ie in range) a latch pulse is required when the main integrator crosses zero. This event produces the P_H signal, and hence the arrival of this signal is used to generate the latch pulse. In over-range, the arrival of the O/R signal is used, as this occurs on the arrival of a 19999 decode pulse. For a wrong function measurement, the arrival of the W/F signal occurs when 0000 is in the counter; hence this is used to produce a latching pulse. In the Dissipation Factor mode, signals from the dissipation factor board are used to produce latching pulses for the R/G/D display. These signals are combined by integrated circuits 4, 5 and 6 to produce the two latching outputs.

A blanking output for the C/L display is generated by O/R and W/F signals. For the R/G/D display, blanking pulses are generated for O/R, W/F and dissipation factor over-range. These signals are generated by integrated circuits 1, 2 and 3. The latching and display blanking outputs are connected to the counter/store and display boards respectively.

7.9 **Switch Board** Refer to Circuit Diagram, page 71.
This board contains the switches which command range and function, together with a light emitting diode display of range, function and mode.

The range switches are of the momentary contact type. Their outputs are binary coded by IC1 to IC3 and a 'range selected' signal is generated. These outputs are 0 V to −10 V logic and are used to latch the selected range on the Auto-Range and Function Logic board. The range information from the Auto-Range and Function Logic board is buffered by a transistor stage which drives an l.e.d. to indicate in which range the instrument is; these inputs are 0 V to −15 V. Function (L, C, AUTO, REMOTE) l.e.d.'s are driven by the same method; these inputs are 0 V to −10 V.

7.10 **Auto Range and Function Logic Board** Refer to Circuit Diagram, page 73.
This board can be divided into three parts: Range logic, Function logic and Data Ready.

Range Logic
The heart of this circuit is a pre-set up/down counter (IC12), which stores the range code. The output is level-changed and buffered (IC9) to provide the T.T.L. compatible range code output. The output of the counter is also level changed (TR2 to TR4) and decoded (IC13) to provide range information for the instrument (0V to −15V).

When the instrument is used in the manual range command mode, the pre-set inputs of the counter (IC12) are connected via an active switch (IC15) to the binary coded range outputs of the switch board. When a range switch is pressed on this board, the 'range selected' output causes a logic 1 (0V) on the pre-set enable input of the counter (IC12) allowing the selected range code to be set in the counter.

When a range code is connected to the external range command inputs, this is detected (IC9), and if the instrument was previously in the fully automatic mode the remote mode is commanded. The external range inputs are buffered (TR6 to TR8) and connected via a switch (IC16) to the pre-set inputs of the counter (IC12).

In the auto-range mode, the counter counts up or down automatically to find the correct range. The counter IC12 is clocked by the arrival of an O/R, or by an under-range signal in Phase 4 if there was also an under-range signal in P_2, ie both the real and imaginary components of measurement are under-range. The U/R signal in P_2 is stored on a J.K. flip-flop (IC8 pins 1 to 7). The counter counts up or down depending on the function the measurement was made in (stored on IC8 pins 9 to 15) and whether or not the measurement is over-range. These signals are combined (IC5) to produce a control signal connected to the up/down input of the counter (IC12 pin 10). The clock signal is dis-enabled when the counter is about to count up in range 6 or down in range 0. In manual and remote modes the clock is also dis-enabled.

Function Logic
The function (L/R or C/G) is stored on a J.K. flip-flop (IC20 pins 1 to 7). In the manual mode its output is set and re-set by pulses from the L/R and C/G command switches on the switch board. In the remote mode, its output is set and re-set according to the logic level on the remote function input. The re-set and Set inputs of the flip-flop (IC20 pins 1 to 7) are digitally connected to the L/R and C/G switches, or to the remote function input, via IC10 and IC11. Auto function is achieved by clocking the flip-flop (IC20 pins 1 to 7) causing it to change state. If the instrument is measuring in the wrong function, the measurement of the imaginary component is negative causing the output of the Wrong Function comparator to be a logic 1. If this is the case for two measurement cycles, a clock pulse is produced by IC20 (pins 9 to 15) at the end of phase P_3, which clocks the flip-flop storing the function information (IC20 pins 1 to 7).

Auto Range and Function
Auto range and auto function are stored in IC23 pins 1 to 7 and 8 to 15 respectively. Pressing the AUTO switch places a logic 1 on the set input of these flip-flops, setting auto range and auto function. A logic 1 on the 'range selected' input from the switch board resets both flip-flops into the manual mode. Pressing a function switch cancels the auto function by placing a logic 1 on its reset input. These inputs are combined via IC22 and IC24. When the instrument is switched on, auto range and auto function are automatically selected by C11 and R47.

Data Ready

This is a J.K. flip-flop counter (IC4 and IC5) counting from 0,0 to 1,1 and clocked by $\overline{P}_3$ and P_1. When the counter reaches 1,1 the instrument will have made sufficient measurements to display the correct value of the unknown component. The 1,1 signals are combined to produce the Data Ready signal. The counter is reset to 0,0 by three signals: (a) a positive transition on the Run/Stop input, (b) in the auto range mode, a clocking signal on the range counter (IC12), and (c) in the auto function mode, by a negative measurement at the end of the P_3 phase (ie wrong function signal). These signals are combined and stored by integrated circuits 1, 2 and 3.

7.11 **Dissipation Factor Board** Refer to Circuit Diagram, page 65.

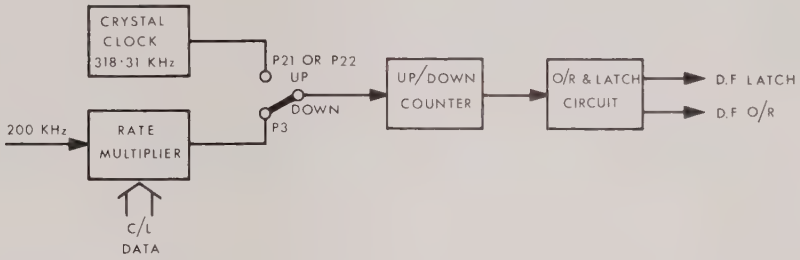


Fig.11

Dissipation factor (tanδ) is defined as $\frac{G}{\omega C}$ or $\frac{R}{\omega L}$. The function of the dissipation factor board is to digitally calculate the dissipation factor from the measured data.

During P_{21} and P_{22} (this time is proportional to G or R), the UP/DOWN counter is counting up with a clock frequency of $\frac{10^6}{\pi}$. At the end of P_{22} the number in the counter will be proportional to $\frac{G}{\pi}$. During P_3 the UP/DOWN counter counts down to zero, clocked by the output of a rate multiplier. The output frequency of the rate multiplier is the 200 kHz main counter frequency multiplied by the number shown on the C/L display.

When the UP/DOWN counter reaches zero,

$$\frac{G}{\pi} \alpha \text{ 200 kHz x Ct} \quad \text{ie} \quad t\alpha \frac{G}{2\pi fC} \quad \alpha \text{ D.F.}$$

where t is the time taken for the counter to count down to zero, and is proportional to the dissipation factor. Hence, with the correct scaling constant, at the zero crossing of the UP/DOWN counter the number in the main counter (counter/store board) will be equal to the dissipation factor. This number is latched into the R/G/D store and displayed.

Dissipation Factor Calculation Cycle

During P_1 the UP/DOWN counter (IC1, IC4, IC6, IC9) is set to zero, ready for the calculation. Next it counts up from zero during the P_{21} and P_{22} phases, with a clock frequency of 318,31 kHZ ($\frac{10^6}{\pi}$). This is obtained from a quartz crystal oscillator (XL1, IC15 and associated components) via IC14, IC7 and IC10. In the next phase P_3, the counter counts down to zero. Its clock input is connected to the output of a 4½ digit rate multiplier (IC3, IC5, IC8, IC11), which operates on a 0V to +5V supply and has an input frequency of 200 kHz, the output of the phase lock loop on the oscillator board. The 200 kHz, square wave is level changed and connected to two R–C monostables (R10, R11, C5, C6 and IC13) to produce two 200 kHz pulse trains with pulses approximately 1μs wide, 180° out of phase. One is used to clock a 4 digit rate multiplier, and the other is gated (IC2) with the most significant digit of the C/L data to produce the extra half digit of the rate multiplier. The output of the rate multiplier is a series of pulses with an average frequency proportional to the number shown on the C/L display. The output of the rate multiplier is then level changed to 0V to 10V logic levels (TR1 and associated components) and gated with P_3 (IC7) and used to clock the UP/DOWN counter in the down mode.

When the counter has counted down to zero the number in the main counter (counter/store board) is the calculated dissipation factor. The zero is decoded in the counter in the form of a carry out pulse; this is used as a latch pulse to transfer data from the counter to the store on the counter/store board, via IC10 and IC17 and the control logic board.

Dissipation factor over-range is defined as the state in which the counter zero has not occurred when the main counter reaches 10000. The arrival of a 10000 decode signal is used to clock a J.K. flip-flop (IC16 pins 1 to 7) that stores the over-range signal.

The dissipation factor mode is stored on a J.K. flip-flop (IC16 pins 9 to 15). Pressing the dissipation factor command switch on the display board clocks the flip-flop, which changes state. The effects of switch contact bounce are suppressed by C9, C11 and C13, R17, R19, R24 and R25. In the remote mode, the dissipation factor external input sets or resets this flip-flop via IC10 and IC12. When the instrument is switched on, C7 and R15 reset the flip-flop, automatically selecting the Not D.F. mode.

7.12 **Power Supply Board** Refer to Circuit Diagram, page 61.
The a.c. supplies (approximately 18,5 V, 18,5 V, 9,5 V r.m.s.) are full wave rectified by rectifying bridges B1, B2 and B3. The output of bridge 1 is smoothed by C9 and regulated by an integrated circuit regulator (IC1) to give an output of +15 V. The output of bridge 2 is smoothed by C10 and regulated by IC2 to generate the -15V supply. The -10V supply is derived from the -15V supply by an integrated circuit regulator IC5. Finally the output of B3 is smoothed by C11, and two integrated circuit regulators (IC3 and IC4) are used to produce the two + 5V supplies. The power supply outputs are connected to the appropriate terminal pins on the mother board.

8.0 SERVICE AND MAINTENANCE

THIS IS A MAINS OPERATED INSTRUMENT. Wherever possible repair work should be carried out with the power disconnected. TAKE EXTREME CARE WHEN CARRYING OUT FAULT-FINDING WORK WITH THE INSTRUMENT COVER REMOVED.

8.1 General

The Sullivan AC5555 is a complex instrument including many integrated circuits and CMOS logic. Servicing should not be attempted without experience of operational amplifier techniques and CMOS logic, or without the necessary equipment. The exception to this is the Calibration Procedure (Section 8.5) which can be performed with the minimum equipment. It is recommended that the service engineer reads the circuit descritpion and then uses this in conjunction with the circuit diagrams, printed circuit board lay-outs and parts lists in order to locate faults. If in doubt about your capabilities to service this instrument, please return it to the London Instrument Repair Centre at Dover.

THIS INSTRUMENT CONTAINS CMOS LOGIC CIRCUITRY. PRECAUTIONS SHOULD BE TAKEN AT ALL TIMES TO PREVENT BUILD UP OF STATIC CHARGE IN ORDER TO AVOID DAMAGE TO COMPONENTS.

8.2 Cleaning of Instrument Case

The front panel and instrument case may be cleaned using a damp cloth and mild detergent. Do not use organic solvents as these may damage the finish of the front panel. Ensure that the surface is completely dry before reconnecting the instrument to the power supply.

8.3 Access

8.3.1 Removal of Top of Instrument

Remove the two top screws from each side of the instrument case and lift off the case top. It is not necessary to remove the rack mounting brackets if fitted; the top can be slid backwards.

8.3.2 Removal of Printed Circuit Boards

With the exception of the power supply printed circuit board, all boards are mounted vertically in sockets in the mother board. To remove an individual board, simply pull it upwards out of the socket. For the layout of the printed circuit boards, see the Instrument Circuit Diagram, page 00.

8.3.3 Use of Extension Cards

A set of extension cards is available for servicing, as an optional accessory, Part No. 6220–132. The set comprises four cards which plug into the sockets in the mother board; the printed circuit board to be investigated is then plugged into the top of the extension card. The extension card to be used with each board can be identified as follows:

Board	Card No.
Ranging Amplifier	5340–172
Phase Sensitive Detector	5340–172
Control Logic	5340–172
Auto-Range and Function Logic	5340–173
Counter/Store	5340–174
Dissipation Factor	5340–175
Oscillator	5340–175

8.4 Servicing Notes

The complexity of the instrument is such that it is impossible to give a complete fault-finding guide. In many cases the nature of the fault will be evident from the information displayed on the front panel. When the source of the fault is not clear, the following procedure may be helpful in locating the area of the fault:

(a) Check the power supply output voltages, which can be found on the mother board behind the power supply tray, terminal pins 3 to 9.

Pins	Output Voltage
8–7	0 V
8–9	+5 V ± 5%
8–4	+5 V ± 5%
8–6	−10 V ± 5%
8–5	−15 V ± 5%
8–3	+15 V ± 5%

(b) Connect a known resistor (R_x) to the measurement terminals and measure V_x and V_r relative to 0 V An (0 Volts analogue), ranging amplifier socket pins 11, 13 and 36 respectively. V_r should be 1,000 V r.m.s. (± 0,5%), V_x should be 1 V r.m.s. and 180° out of phase with V_r, for the following resistors on the following ranges:

Range	Resistor connected to measurement terminals (R_x)
0	1 MΩ
1	100 kΩ
2	10 kΩ
3	1 kΩ
4	100 kΩ
5	10 Ω
6	1 Ω

(c) Check that the phase signals are correct (see Section 7, Figs. 2 and 3). It is suggested that the oscilloscope is triggered on the positive edge of P_1. All the phase signals are available on the Control Logic socket. (See the circuit diagram for the relevant signals and their pin-outs on the edge connector).

(d) Check the output voltage of the main integrator on the P.S.D. Board, IC3 pin 6. This should be of the correct form for the component being measured; the P_1 and P_2 ramps concern the Resistive/Conductive part of the measurement and P_3 and P_4 concern the capacitive/inductive part. (See Fig. 3 in Technical Description).

(e) Check that the output voltages of the comparators IC4, IC8 and IC9 on the P.S.D. Board are correct for their input voltages. The outputs are 0 to −10 V logic levels.

(f) If the fault is of the type that affects the interaction between the two measurement components, e.g. phase shifts and faults in the error correction system, it may be helpful to disconnect the output of the error correction system from the input of the main integrator. This can be achieved by removing the link between the terminal pins 1 and 2 on the P.S.D. Board.

After the completion of any repair involving a change of component, the instrument should be set-up and recalibrated, as outlined in the following two sections.

8.5 Setting-Up Procedure

8.5.1 Test Gear Required

Digital Voltmeter 0,1% d.c. 0,2% a.c. at 1 kHz e.g. DA114
Oscilloscope
Counter for 1 kHz
Extender cards, Part No. 6220–132
100 pF capacitor 20% or better
10 nF capacitor 10%
1 MΩ resistor 20% or better
10 kΩ resistor 10% or better
1 kΩ carbon composition resistor 20% or better
1 nF, 10 nF or 100 nF capacitor, silver mica, of known conductance

8.5.2 **Procedure**

(a) *Ranging Amplifier Board*

Place the Ranging Amplifier Board in the mainframe via its extender card, Part No. 5340–172, and switch on the instrument. Connect a voltmeter across R34 or R35 (2,2Ω resistors) and adjust R29 on this board so that the voltmeter reads 50 mV ± 5 mV. This sets the bias current through the output transistors TR22 and TR24. Switch off the instrument and replace the Ranging Amplifier Board without its extension card.

(b) *Oscillator Board*

Place the Oscillator Board in the mainframe via its extender card, Part No. 5340–175, and switch on the instrument. Select the 2 μF–20 mS range.

(i) Connect a voltmeter across R1 on the Oscillator Board and adjust the pre-set resistor R9 to set the d.c. voltage across R1 to 100 mV ± 10 mV. This sets the bias current through the output transistors. Disconnect the voltmeter.

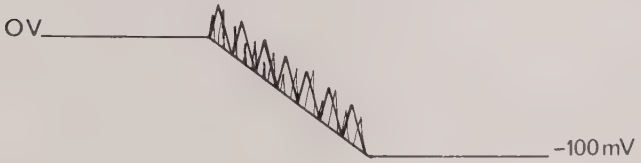
(ii) Connect a frequency meter between the I+ terminal and the G terminal on the front panel, with the G terminal to the 'earthy' side of the frequency meter. Then adjust R24 on the Oscillator Board to set the measurement frequency to 1,000 kHz ± 2 Hz.

(iii) Leaving the frequency meter connected, connect an a.c. voltmeter between terminal pin 1 and the front panel guard terminal. Adjust R25 on the Oscillator Board to set the amplitude of the 1 kHz signal to 2,5 V r.m.s. ± 0,1 V. Check that the frequency is unaltered, but if it has changed go back to step (ii). Remove the voltmeter and the frequency meter.

(iv) Connect a high input impedance digital d.c. voltmeter (1 MΩ impedance or larger) between terminal pin 2 and the front panel guard terminal. Adjust R31 on the Oscillator Board to set this voltage to 1,000 V ± 1 mV. Disconnect the voltmeter.

(v) Connect an a.c. voltmeter between the I+ terminal and the guard terminal on the front panel. Adjust R76 on the Oscillator Board to set this voltage to 1,000 V r.m.s. ± 2 mV. This is the instrument's measurment signal level.

(vi) Switch off the instrument and place the P.S.D. Board in position on its extender card, Part No. 5340–172. Switch on the instrument and connect a 10 kΩ resistor to the measurement terminals. Select the L/R range 20 kΩ/2H. Connect an oscilloscope input to terminal pin 3 on the P.S.D. card. The 'scope should be triggered on the positive edge of the phase signal P1, available on the gate of TR39 on the P.S.D. Board. Adjust R35 on the Oscillator Board so that the ramp displayed on the 'scope has a final amplitude of −100 mV ± 10 mV. Remove the 'scope and switch off the instrument. Replace the Oscillator Board in position without its extender.



(c) *P.S.D. and Integrator Board*

(i) Connect a 100 pF (20% or better) capacitor to the measurement terminals and set the instrument to range 4 (2 μF/20 mS range). Adjust R26 on the P.S.D. Board so that the left-hand capacitance display reads .0001 μF. This sets the zero of the C/L display. Disconnect the capacitor.

(ii) Connect a 1 MΩ (20% or better) resistor to the measurement terminals and with the instrument set to range 4 adjust R53 on the P.S.D. Board so that the conductance display (right hand) reads 0.001 mS. This sets the zero of the G/R display. Remove the resistor.

(iii) Connect a 10 kΩ (10% or better) resistor to the measurement terminals and set the instrument to range 3 (20 nF/200 μS). Note the displayed value of the conductance. Now connect terminal pin 4 to the guard terminal on the front panel. Adjust R22 on the P.S.D. Board so that the new displayed conductance is the same as the previously noted value ± 1 digit. This sets the third ramp slope for the G/R measurement. Disconnect pin 4 and the 10 kΩ resistor.

(iv) Connect a 10 nF (10% or better) capacitor to the measurement terminals and set the instrument to range 3 (20 nF/200 μS). Note the displayed value of capacitance. Now reconnect terminal pin 4 to the guard terminal on the front panel. Adjust R20 on the P.S.D. card so that the new displayed reading is the same as the previously noted value ± 1 digit. This sets the third ramp for the C/L measurement. Disconnect pin 4 from the guard terminal and remove the capacitor.

(v) Connect a carbon composition 1 kΩ (20% or better) resistor to the measurement terminals, and set the instrument to range 4 (200 nF/2 mS). Adjust R34 on the P.S.D. Board so that the capacitance display reads 00.00 nF (with no negative sign). Remove the resistor.

(vi) Connect a 1 nF, 10 nF, or 100 nF silver mica capacitor of a known conductance to the measurement terminals. Adjust R35 on the P.S.D. Board so that the correct conductance is displayed on the right-hand display. These last two adjustments set the interaction error between the two phases of the measurement.

8.6 Calibration Procedure

Recalibration of the instrument is a simple process involving nine adjustments. The following standards are required:

Standard resistors, accuracy 0,1% or better. One each of the following values:

1 MΩ, 100 kΩ, 10 kΩ, 1 kΩ, 100 Ω, 10 Ω, 1 Ω.

One standard capacitor, accuracy 0,1% to 0,01%. The value may be any of the following:

1 nF, 10 nF, or 100 nF.

The accuracy of the instrument depends on the accuracy of these standards, so the highest accuracy standards available should be used.

The procedure is as follows. If it is required only to check the calibration, follow the same procedure without removing the top of the instrument case or making any adjustments.

(a) Remove the two top screws from each side of the instrument case and lift off the case top. It is not necessary to remove the rack mounting brackets if fitted; the top can be slid backwards. The adjustment potentiometers are located on the Phase Sensitive Detector (PSD) board and the Ranging Amplifier board, both on the right-hand side of the instrument.

(b) Select range 2 (20 kΩ range) and connect the 10 kΩ standard resistor across the terminals in the normal way. By depressing the L/R button, a reading of approximately 10.000 kΩ will be obtained on the right-hand display. By depressing the C/G button, the reading will be approximately 100.00 μS).

(c) The two potentiometers for the function adjustments are towards the left side of the Phase Sensitive Detector board. The R/G potentiometer is the right of these two, labelled R2. Using a screw-driver, turn this adjustor until the R and G readings, obtained by alternately depressing the two function buttons, are equi-distant from 10000 (disregarding the decimal point), eg 10004 and 9996. This adjustment is common to all resistance and conductance ranges.

(d) Select the Auto Range and L/R function. Locate the metal box on the Ranging Amplifier board. Inside this box are the potentiometers for ranges 0 to 5, in exactly the same order as the range buttons, accessible through the top of the box. The potentiometer for range 2 is the third from the left. Turn this adjustor until the R reading is as near as possible to 10000. Range 2 is now calibrated for resistance and conductance.

(e) Repeat step (d) for ranges 0, 1, 5, 6, 4, 3 using the 1MΩ, 100 kΩ, 10 Ω, 1 Ω, 100 Ω and 1 kΩ standard resistors in this order. Remember to use four terminal connections for ranges 5 and 6. The potentiometers for ranges 0 to 5 are inside the metal box on the Ranging Amplifier board; the potentiometer for range 6 is to the left side of the same board, labelled R68. All the resistance and conductance ranges are now calibrated.

(f) Select AUTO and connect the standard capacitor to the instrument. A reading of approximately 10000 will be obtained on the left-hand display.

(g) The C/L potentiometer is the left-hand of the pair on the Phase Sensitive Detector board, labelled R6. Turn this adjustor until the reading on the left-hand display is as close as possible to 10000. This single adjustment calibrates all the capacitance and inductance ranges, since all the range resistors have already been set.

(h) Replace the top of the instrument before commencing with normal measurements.

9.0 COMPONENTS LISTS

9.1 Instrument Assembly

Circuit Reference	Description	Part No.
R3	Resistor 1 kΩ ± 5% 0,33 W	26351–090
C9	Capacitor 4700 pF 25 V	27889–530
C10	Capacitor 4700 pF 25 V	27889–530
C11	Capacitor 10 mF 16 V	27889–531
C12	Capacitor 10 nF + 100% − 0% 1400 V	27889–284
D1	Diode 1N4148	28433–801
D2	Diode 1N4148	28433–801
FS1	Fuse link 250 mA T (slow-blow) 250 V	25413–256
PL1	Mains socket	25424–859
S1	Lever switch (ON/OFF)	25454–287
S2	Rocker switch (DC Bias)	25455–307
SKT2	Fixed socket 29 way	25436–248
SKT3	Fixed socket 29 way	25436–248
SKT4	Fixed socket 17 way	25436–246
SKT5	Edge connector 60 way (Oscillator p.c.b.)	25441–459
SKT6	Edge connector 60 way (Dissipation factor p.c.b.)	25441–459
SKT7	Edge connector 60 way (Counter store p.c.b.)	25441–459
SKT8	Edge connector 60 way (Display p.c.b.)	25441–459
SKT9	Edge connector 47 way (Switch p.c.b.)	25441–460
SKT10	Edge connector 47 way (Auto range p.c.b.)	25441–460
SKT11	Edge connector 47 way (Ranging amplifier p.c.b.)	25441–460
SKT12	Edge connector 47 way (Phase sensitive detector p.c.b.)	25441–460
SKT13	Edge connector 47 way (Control logic p.c.b.)	25441–460
T1	Transformer assembly	6230–776
Term 1	Terminal 1, I+, grey	25267–723
Term 2	Terminal 2, P+, grey	25267–723
Term 3	Terminal 3, G, green	25267–720
Term 4	Terminal 4, P−, grey	25267–723
Term 5	Terminal 5, I−, grey	25267–723
VS1	Voltage selector	25448–186
	Fuse holder	25416–712
	Front panel, printed, assembly	6330–986

9.2 Power Supply Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed Circuit Board Assembly				6330–315
R1	Resistor	2,2 kΩ	± 5%	0,33 W	26351–095
R2	Resistor	7,5 kΩ	± 5%	0,33 W	26835–088
C1	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C2	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C3	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C4	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C5	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C6	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C7	Capacitor	0,1 μF	+ 50% – 20%		27888–798
C8	Capacitor	2,2 μF	± 20%	63 V	27889–534
B1	Rectifier Bridge	ISB05			28862–847
B2	Rectifier Bridge	ISB05			28862–847
B3	Rectifier Bridge	KBP–02			28863–136
IC1	Voltage Regulator	7815			28863–137
IC2	Voltage Regulator	7815			28863–137
IC3	Voltage Regulator	7805			28863–138
IC4	Voltage Regulator	7805			28863–138
IC5	Variable Voltage Regulator	μA79MGT2C			28863–139

9.3 Oscillator Printed Circuit Board

Circuit Reference	Description					Part No.
	Printed Circuit Board Assembly					6330–316
R1	Resistor	15 Ω	±	10%	5 W	26835–909
R2	Resistor	56 Ω	±	5%	0,33 W	26835–178
R3	Resistor	2,2 Ω	±	5%	0,33 W	26835–901
R4	Resistor	2,2 Ω	±	5%	0,33 W	26835–901
R5	Resistor	15 Ω	±	10%	5 W	26835–909
R6	Resistor	56 Ω	±	5%	0,33 W	26835–178
R7	Resistor	15 kΩ	±	5%	0,33 W	26351–115
R8	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R9	Potentiometer	10 kΩ	±	10%	0,25 W	27284–697
R10	Resistor	27 kΩ	±	5%	0,33 W	26351–123
R11	Resistor	15 kΩ	±	5%	0,33 W	26351–115
R12	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R13	Resistor	2,2 kΩ	±	5%	0,33 W	26351–095
R14	Resistor	2,2 kΩ	±	5%	0,33 W	26351–095
R15	Resistor	220 kΩ	±	5%	0,33 W	26351–134
R16	Resistor	3,9 kΩ	±	5%	0,33 W	26351–097
R17	Resistor	470 Ω	±	5%	0,33 W	26351–082
R18	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R19	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R20	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R21	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R22	Resistor	1,1 kΩ	±	2%	0,5 W	26834–456
R23	Resistor	910 Ω	±	2%	0,5 W	26834–454
R24	Potentiometer	200 Ω	±	10%	0,75 W	27889–514
R25	Potentiometer	470 Ω	±	10%	0,25 W	27284–748
R26	Resistor	1,5 kΩ	±	5%	0,33 W	26351–093
R27	Resistor	2,7 kΩ	±	5%	0,33 W	26351–096
R28	Resistor	820 Ω	±	5%	0,33 W	26351–088
R29	Resistor	2,2 kΩ	±	5%	0,33 W	26351–095
R30	Resistor	2 kΩ	±	2%	0,5 W	28634–462
R31	Potentiometer	200 Ω	±	10%	0,75 W	27889–514
R32	Resistor	360 Ω	±	2%	0,5 W	26834–444
R33	Resistor	910 Ω	±	2%	0,5 W	26834–454
R34	Resistor	1,5 kΩ	±	2%	0,5 W	26834–459
R35	Potentiometer	200 Ω	±	10%	0,75 W	27889–514
R36	Resistor	1,6 kΩ	±	2%	0,5 W	26834–460
R37	Resistor	1 kΩ	±	5%	0,33 W	26351–090
R38	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R39	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R40	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R41	Resistor	470 kΩ	±	2%	0,5 W	26834–490
R42	Resistor	100 kΩ	±	2%	0,5 W	26835–403
R43	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R44	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R45	Resistor	10 kΩ	±	2%	0,5 W	26835–401
R46	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R47	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R48	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R49	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R50	Resistor	100 Ω	±	5%	0,33 W	26351–055
R51	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R52	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R53	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R54	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R55	Resistor	100 kΩ	±	5%	0,33 W	26834–650

Circuit Reference	Description				Part No.
R56	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R57	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R58	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R59	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R60	Resistor	160 Ω	± 2%	0,5 W	26834–436
R61	Resistor	4,7 kΩ	± 2%	0,5 W	26835–396
R62	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R63	Resistor	360 Ω	± 2%	0,5 W	26834–444
R64	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R65	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R66	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R67	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R68	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R69	Resistor	15 kΩ	± 2%	0,5 W	26834–483
R70	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R71	Resistor	15 kΩ	± 2%	0,5 W	26834–483
R72	Resistor	20 kΩ	± 2%	0,5 W	26834–486
R73	Resistor	10 kΩ	± 2%	0,5 W	26835–401
R74	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R75	Resistor	22 kΩ	± 2%	0,5 W	26834–487
R76	Potentiometer	5 kΩ	±10%	0,75 W	27889–518
R77	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R78	Resistor	270 kΩ	± 5%	0,33 W	26351–135
R79	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R80	Resistor	270 kΩ	± 5%	0,33 W	26351–135
R81	Resistor	270 kΩ	± 5%	0,33 W	26351–135
R82	Resistor	47 kΩ	± 5%	0,33 W	26351–126
R83	Resistor	390 kΩ	± 5%	0,33 W	26834–715
R84	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R85	Resistor	2,2 kΩ	± 5%	0,33 W	26351–095
R86	Resistor	22 kΩ	± 5%	0,33 W	26834–228
R87	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R88	Resistor	10 MΩ	±10%	0,33 W	26341–820
R89	Resistor	13 kΩ	± 2%	0,5 W	26834–482
R90	Resistor	18 kΩ	± 2%	0,5 W	26834–485
R91	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R92	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R93	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R94	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R95	Resistor	220 kΩ	± 5%	0,33 W	26351–134
R96	Resistor	560 Ω	± 5%	0,33 W	26351–083
C1	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C2	Capacitor	470 µF		16 V	27888–804
C3	Capacitor	100 pF			27888–801
C4	Capacitor	47 pF			27889–006
C5	Capacitor	0,1 µF	±20%	100 V	27889–500
C6	Capacitor	1 nF	±20%		27889–507
C7	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C8	Capacitor	10 µF		16 V	27888–796
C9	Capacitor	10 µF		16 V	27888–796
C10	Capacitor	0,1 µF	+50% -20%	30 V	27888–798

Circuit Reference	Description				Part No.
C11	Capacitor	6,8 nF	±20%	160 V	27889–509
C12	Capacitor	15 nF	± 5%		27889–497
C13	Capacitor	0,15 µF	± 2%	63 V	27889–492
C14	Capacitor	0,15 µF	± 2%	63 V	27889–492
C15	Capacitor	10 µF		16 V	27888–796
C16	Capacitor	100 µF		3 V	27889–061
C17	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C18	Capacitor	0,1 µF	± 2%	63 V	27889–540
C19	Capacitor	0,1 µF	± 2%	63 V	27889–540
C20	Capacitor	0,15 µF	± 5%	100 V	27889–498
C21	Capacitor	15 nF	± 5%		27889–497
C22	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C23	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C24	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C25	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C26	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C27	Capacitor	10 nF	±20%		27889–499
C28	Capacitor	10 nF	±20%		27889–499
C29	Capacitor	10 nF	±20%		27889–499
C30	Capacitor	10 nF	±20%		27889–499
C31	Capacitor	10 nF	±20%		27889–499
C32	Capacitor	0,1 µF	+50% -20%	30 V	27888–798
C33	Capacitor	22 nF	± 5%		27889–494
C34	Capacitor	2,2 µF	±20%	63 V	27889–508
C35	Capacitor	4,7 nF	±10%		27889–504
C36	Capacitor	4,7 nF	±10%		27889–504
C37	Capacitor	0,68 µF	± 5%		27889–503
C38	Capacitor	100 pF			27888–801
C39	Capacitor	470 pF	± 5%		27889–219
C40	Capacitor	10 nF	±20%		27889–499
C41	Capacitor	1 nF	±20%		27889–507
C42	Capacitor	1 nF	±20%		27889–507
C43	Capacitor	10 nF	±20%		27889–499
C44	Capacitor	3,3 nF	±20%		27889–496
C48	Capacitor	33 nF	±20%	250 V	27889–536
C49	Capacitor	330 pF	± 2%	63 V	27888–806
D1	Diode	1N5338			28863–114
D2	Diode	1N5338			28863–114
D3	Diode	1N4148			28433–801
D4	Diode	1N4148			28433–801
D5	Diode	1N4148			28433–801
D6	Diode	1N3497			28862–852
D7	Diode	1N4148			28433–801
D8	Diode	1N4148			28433–801
D9	Diode	1N4148			28433–801
D10	Diode	1N4148			28433–801
D11	Diode	1N4148			28433–801
D12	Diode	1N4148			28433–801
D13	Diode	1N4148			28433–801
D14	Diode	1N4148			28433–801
D15	Diode	1N4148			28433–801

Circuit Reference	Description		Part No.
TR1	Transistor	2N3053	28862–842
TR2	Transistor	BC183	28554–842
TR3	Transistor	BC183	28554–842
TR4	Transistor	2N2905A	28862–861
TR5	Transistor	BC213	28534–844
TR6	Transistor	BC183	28554–842
TR7	Transistor	BC183	28554–842
TR8	Transistor	E112	28862–846
TR9	Transistor	E112	28862–846
TR10	Transistor	E105	28863–109
TR11	Transistor	E105	28863–109
TR12	Transistor	E108	28863–108
TR13	Transistor	E108	28863–108
TR14	Transistor	BC213	28534–844
TR15	Transistor	BC183	28554–842
TR16	Transistor	BC183	28554–842
TR17	Transistor	E108	28863–108
TR18	Transistor	BC183	28554–842
TR19	Transistor	E108	28863–108
TR20	Transistor	BC183	28554–842
TR21	Transistor	BC183	28554–842
TR22	Transistor	BC183	28554–842
TR23	Transistor	BC183	28554–842
TR24	Transistor	BC213	28534–844
TR25	Transistor	BC213	28534–844
IC1	Integrated circuit 741C		28862–856
IC2	Integrated circuit 741C		28862–856
IC3	Integrated circuit 741C		28862–856
IC4	Integrated circuit 741C		28862–856
IC5	Integrated circuit LM311N		28863–112
IC6	Integrated circuit 4001		20000–001
IC7	Integrated circuit 4001		20000–001
IC8	Integrated circuit 4016		20000–016
IC9	Integrated circuit 741C		28862–856
IC10	Integrated circuit 741C		28862–856
IC11	Integrated circuit 4046		20000–046
IC12	Integrated circuit 4001		20000–001
IC13	Integrated circuit 4001		20000–001
IC14	Integrated circuit 4027		20000–027
IC15	Integrated circuit 4011		20000–011
IC16	Integrated circuit 4011		20000–011
IC17	Integrated circuit 4011		20000–011

9.4 Dissipation Factor Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed circuit board assembly				6330–317
R1	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R2	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R3	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R4	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R5	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R6	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R7	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R8	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R9	Resistor	56 kΩ	± 5%	0,33 W	26351–127
R10	Resistor	15 kΩ	± 5%	0,33 W	26351–115
R11	Resistor	15 kΩ	± 5%	0,33 W	26351–115
R12	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R13	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R14	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R15	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R16	Resistor	10 MΩ	± 5%	0,33 W	26341–820
R17	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R18	Resistor	330 kΩ	± 5%	0,33 W	26351–136
R19	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R20	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R21	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R22	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R23	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R24	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R25	Resistor	1 MΩ	± 5%	0,33 W	26351–140
C1	Capacitor	0,1 µF	+50% −20%	30 V	27888–798
C2	Capacitor	10 pF	± 0,25 pF	63V	27888–795
C3	Capacitor	22 pF	± 2%	63 V	27888–794
C4	Capacitor	0,1 µF	+50% −20%	30 V	27888–798
C5	Capacitor	100 pF	± 2%	63 V	27888–801
C6	Capacitor	100 pF	± 2%	63 V	27888–801
C7	Capacitor	1 µF	± 5%	63 V	27889–493
C8	Capacitor	47 pF	± 2%	63 V	27889–006
C9	Capacitor	0,1 µF	+50% −20%	30 V	27888–798
C10	Capacitor	68 pF	± 2%	63 V	27889–490
C11	Capacitor	0,1 µF	+50% −20%	30V	27888–798
C12	Capacitor	22 pF	± 2%	63 V	27888–794
C13	Capacitor	0,1 µF	+50% −20%	30 V	27888–798
TR1	Transistor	BC213			28534–844
TR2	Transistor	BC213			28534–844
IC1	Integrated circuit 4029				20000–029
IC2	Integrated circuit 4011				20000–011
IC3	Integrated circuit 4527				20000–527
IC4	Integrated circuit 4029				20000–029
IC5	Integrated circuit 4527				20000–527
IC6	Integrated circuit 4029				20000–029
IC7	Integrated circuit 4011				20000–011
IC8	Integrated circuit 4527				20000–527

Circuit Reference	Description	Part No.
IC9	Integrated circuit 4029	20000–029
IC10	Integrated circuit 4001	20000–001
IC11	Integrated circuit 4527	20000–527
IC12	Integrated circuit 4011	20000–011
IC13	Integrated circuit 4050	20000–050
IC14	Integrated circuit 4011	20000–011
IC15	Integrated circuit 4011	20000–011
IC16	Integrated circuit 4027	20000–027
IC17	Integrated circuit 4001	20000–001
XL1	Crystal 318,310 kHz	28863–127

9.5 Counter/Store Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed circuit board assembly				6330–318
R1	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R2	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R3	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R4	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R5	Resistor	5,6 kΩ	± 5%	0,33 W	26351–103
R6	Resistor	5,6 kΩ	± 5%	0,33 W	26351–103
R7	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R8	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R9	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R10	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R11	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R12 to R19	Resistor module	68 kΩ			26835–894
R20 to R34	Resistor module	100 kΩ			26835–893
R35 to R42	Resistor module	68 kΩ			26835–894
R43	Resistor	33 kΩ	± 5%	0,33 W	26351–124
R44	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R45	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R46	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R47	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R48	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R49 to R56	Resistor module	68 kΩ			26835–894
R57 to R71	Resistor module	100 kΩ			26835–893
R72 to R79	Resistor module	68 kΩ			26835–894
R80	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
C1	Capacitor	22 pF	± 2%	63 V	27888–794
C2	Capacitor	100 pF	± 2%	63 V	27888–801
C3	Capacitor	100 pF	± 2%	63 V	27888–801
C4	Capacitor	0,1 μF	+ 50% - 20%	30 V	27888–798
C5	Capacitor	0,1 μF	+ 50% - 20%	30 V	27888–798
TR1	Transistor	BC213			28534–844
IC1	Integrated circuit 4001				20000–001
IC2	Integrated circuit 4011				20000–011
IC3	Integrated circuit 4027				20000–027
IC4	Integrated circuit 4042				20000–042
IC5	Integrated circuit 4050				20000–050
IC6	Integrated circuit 4042				20000–042
IC7	Integrated circuit 4050				20000–050
IC8	Integrated circuit 4001				20000–001
IC9	Integrated circuit 4011				20000–011
IC10	Integrated circuit 4011				20000–011
IC11	Integrated circuit 4042				20000–042
IC12	Integrated circuit 4001				20000–001
IC13	Integrated circuit 4042				20000–042
IC14	Integrated circuit 4050				20000–050
IC15	Integrated circuit 4027				20000–027
IC16	Integrated circuit 4027				20000–027
IC17	Integrated circuit 4029				20000–029
IC18	Integrated circuit 4042				20000–042
IC19	Integrated circuit 4050				20000–050
IC20	Integrated circuit 4011				20000–011
IC21	Integrated circuit 4001				20000–001

Circuit Reference	Description	Part No.
IC22	Integrated circuit 4029	20000–029
IC23	Integrated circuit 4042	20000–042
IC24	Integrated circuit 4050	20000–050
IC25	Integrated circuit 4029	20000–029
IC26	Integrated circuit 4042	20000–042
IC27	Integrated circuit 4029	20000–029
IC28	Integrated circuit 4042	20000–042
IC29	Integrated circuit 4050	20000–050
IC30	Integrated circuit 4027	20000–027

9.6 Display Printed Circuit Board

Circuit Reference	Description				Part No
	Printed circuit board assembly				6330–319
R1	Resistor	270 Ω	± 5%	0,33 W	26351–077
R2	Resistor	270 Ω	± 5%	0,33 W	26351–077
R3	Resistor	270 Ω	± 5%	0,33 W	26531–077
R4	Resistor	47 kΩ	± 5%	0,33 W	26351–126
R5	Resistor	270 Ω	± 5%	0,33 W	26351– 077
R6 to R12	Resistor module	270 Ω	± 2%		26835–891
R13	Resistor	270 Ω	± 5%	0,33 W	26351–077
R14 to R20	Resistor module	270 Ω	± 2%		26835–891
R21	Resistor	270 Ω	± 5%	0,33 W	26351–077
R22 to R28	Resistor module	270 Ω	± 2%		26835–891
R29 to R35	Resistor module	270 Ω	± 2%		26835–891
R36	Resistor	3,3 kΩ	± 5%	0,33 W	26351–098
R37	Resistor	3,3 kΩ	± 5%	0,33 W	26351–098
R38	Resistor	27 kΩ	± 5%	0,33 W	26351–123
R39	Resistor	47 kΩ	± 5%	0,33 W	26351–126
R40	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R41	Resistor	27 kΩ	± 5%	0,33 W	26351–123
R42	Resistor	47 kΩ	± 5%	0,33 W	26351–126
R43	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R44	Resistor	270 Ω	± 5%	0,33 W	26351–077
R45	Resistor	270 Ω	± 5%	0,33 W	26351–077
R46	Resistor	270 Ω	± 5%	0,33 W	26351–077
R47	Resistor	270 Ω	± 5%	0,33 W	26351–077
R48	Resistor	270 Ω	± 5%	0,33 W	26351–077
R49	Resistor	47 kΩ	± 5%	0,33 W	26351–126
R50	Resistor	330 Ω	± 5%	0,33 W	26351–079
R51 to R57	Resistor module	270 Ω	± 2%		26835–891
R58 to R64	Resistor module	270 Ω	± 2%		26835–891
R65 to R71	Resistor module	270 Ω	± 2%		26835–891
R72 to R78	Resistor module	270 Ω	± 2%		26835–891
R79	Resistor	3,3 kΩ	± 5%	0,33 W	26351–098
R80	Resistor	3,3 kΩ	± 5%	0,33 W	26351–098
R81	Resistor	68 kΩ	± 5%	0,33 W	26351–128
R82	Resistor	5,6 kΩ	± 5%	0,33 W	26351–103
D1	Diode	1N4148			28433–801
D2	Diode	1N4148			28433–801
D3	Diode	1N4148			28433–801
D4	Diode	1N4148			28433–801
D5	Light emitting diode lamp				28863–131
TR1	Transistor	BC183			28554–842
TR2	Transistor	BC183			28554–842
TR3	Transistor	BC213			28534–844
TR4	Transistor	BC213			28534–844
TR5	Transistor	BC213			28534–844
TR6	Transistor	BC213			28534–844
TR7	Transistor	BC213			28534–844
TR8	Transistor	BC213			28534–844
TR9	Transistor	BC213			28534–844
TR10	Transistor	BC213			28534–844
TR11	Transistor	BC213			28534–844
TR12	Transistor	BC213			28534–844
TR13	Transistor	BC213			28534–844
TR14	Transistor	BC183			28554–842
TR15	Transistor	BC183			28554–842

Circuit Reference	Description				Part No.
TR16	Transistor	BC183			28554–842
TR17	Transistor	BC183			28554–842
TR18	Transistor	BC213			28534–844
TR19	Transistor	BC213			28534–844
TR20	Transistor	BC213			28534–844
TR21	Transistor	BC213			28534–844
TR22	Transistor	BC213			28534–844
IC1	Integrated circuit 7447				28863–111
IC2	Integrated circuit 7447				28863–111
IC3	Integrated circuit 7447				28863–111
IC4	Integrated circuit 7447				28863–111
IC5	Integrated Prom. 1				6280–123
IC6	Integrated Prom. 2				6280–124
IC7	Integrated circuit 7447				28863–111
IC8	Integrated circuit 7447				28863–111
IC9	Integrated circuit 7447				28863–111
IC10	Integrated circuit 7447				28863–111
C1	Capacitor	0,1 μF	+50% −20%	30V	27888–798
C2	Capacitor	0,1 μF	+50% −20%	30V	27888–798
S1	Switch (D.F.)				25454–285
Display 1	Light emitting diode display, overflow digit				28863–130
Display 2	Light emitting diode display, full digit				28863–129
Display 3	Light emitting diode display, full digit				28863–129
Display 4	Light emitting diode display, full digit				28863–129
Display 5	Light emitting diode display, full digit				28863–129
Display 6	Light emitting diode display, overflow digit				28863–130
Display 7	Light emitting diode display, full digit				28863–129
Display 8	Light emitting diode display, full digit				28863–129
Display 9	Light emitting diode display, full digit				28863–129
Display 10	Light emitting diode display, full digit				28863–129
Lamp 1	Filament lamp, 60 mA, 5 V				28863–128
Lamp 2	Filament lamp, 60 mA, 5 V				28863–128
Lamp 3	Filament lamp, 60 mA, 5 V				28863–128
Lamp 4	Filament lamp, 60 mA, 5 V				28863–128
Lamp 5	Filament lamp, 60 mA, 5 V				28863–128
Lamp 6	Filament lamp, 60 mA, 5 V				28863–128
Lamp 7	Filament lamp, 60 mA, 5 V				28863–128
Lamp 8	Filament lamp, 60 mA, 5 V				28863–128
Lamp 9	Filament lamp, 60 mA, 5 V				28863–128
Lamp 10	Filament lamp, 60 mA, 5 V				28863–128
Lamp 11	Filament lamp, 60 mA, 5 V				28863–128
Lamp 12	Filament lamp, 60 mA, 5 V				28863–128

9.7 Switch Printed Circuit Board

Circuit Reference	Description					Part No.
	Printed circuit board assembly					6330–320
R1	Resistor	33 kΩ	±	5%	0,33 W	26351–124
R2	Resistor	33 kΩ	±	5%	0,33 W	26531–124
R3 to R9	Resistor module	47 kΩ	±	2%		26835–892
R10	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R11	Resistor	330 Ω	±	5%	0,33 W	26351–079
R12	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R13	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R14	Resistor	330 Ω	±	5%	0,33 W	26351–079
R15	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R16	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R17	Resistor	330 Ω	±	5%	0,33 W	26351–079
R18	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R19	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R20	Resistor	330 Ω	±	5%	0,33 W	26351–079
R21	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R22	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R23	Resistor	330 Ω	±	5%	0,33 W	26351–079
R24	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R25	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R26	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R27	Resistor	330 Ω	±	5%	0,33 W	26351–079
R28	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R29	Resistor	330 Ω	±	5%	0,33 W	26351–079
R30	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R31	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R32	Resistor	330 Ω	±	5%	0,33 W	26351–079
R33	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R34	Resistor	330 Ω	±	5%	0,33 W	26351–079
R35	Resistor	330 Ω	±	5%	0,33 W	26351–079
R36	Resistor	330 Ω	±	5%	0,33 W	26351–079
R37	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R38	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R39	Resistor	33 kΩ	±	5%	0,33 W	26351–124
R40	Resistor	33 kΩ	±	5%	0,33 W	26351–124
R41	Resistor	330 Ω	±	5%	0,33 W	26351–079
R42	Resistor	22 kΩ	±	5%	0,33 W	26834–228
R43	Resistor	33 kΩ	±	5%	0,33 W	26351–124
D1	Light emitting diode lamp					28863–131
D2	Light emitting diode lamp					28863–131
D3	Light emitting diode lamp					28863–131
D4	Light emitting diode lamp					28863–131
D5	Light emitting diode lamp					28863–131
D6	Light emitting diode lamp					28863–131
D7	Light emitting diode lamp					28863–131
D8	Light emitting diode lamp					28863–131
D9	Light emitting diode lamp					28863–131
D10	Light emitting diode lamp					28863–131
D11	Light emitting diode lamp					28863–131
D12	Light emitting diode lamp					28863–131
TR1	Transistor	BC183				28554–842
TR2	Transistor	BC183				28554–842
TR3	Transistor	BC183				28554–842
TR4	Transistor	BC183				28554–842
TR5	Transistor	BC183				28554–842

Circuit Reference	Description		Part No.
TR6	Transistor	BC183	28554–842
TR7	Transistor	BC183	28554–842
TR8	Transistor	BC183	28554–842
TR9	Transistor	BC183	28554–842
TR10	Transistor	BC183	28554–842
TR11	Transistor	BC183	28554–842
TR12	Transistor	BC183	28554–842
IC1	Integrated circuit 4001		20000–001
IC2	Integrated circuit 4011		20000–011
IC3	Integrated circuit 4001		20000–001
S1	'Digitast' switch		25454–285
S2	'Digitast' switch		25454–285
S3	'Digitast' switch		25454–285
S4	'Digitast' switch		25454–285
S5	'Digitast' switch		25454–285
S6	'Digitast' switch		25454–285
S7	'Digitast' switch		25454–285
S8	'Digitast' switch		25454–285
S9	'Digitast' switch		25454–285
S10	'Digitast' switch		25454–285

9.8 Auto Range and Function Logic Printed Circuit Board

Circuit Reference	Description					Part No.
	Printed circuit board assembly					6330–321
R1	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R2	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R3	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R4	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R5	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R6	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R7	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R8	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R9	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R10	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R11	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R12	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R13	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R14	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R15	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R16	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R17	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R18	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R19	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R20	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R21	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R22	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R23	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R24	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R25	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R26	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R27	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R28	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R29	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R30	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R31	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R32	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R33	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R34	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R35	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R36	Resistor	4,7 kΩ	±	5%	0,33 W	26351–101
R37	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R38	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R39	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R40	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R41	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R42	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R43	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R44	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R45	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R46	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R47	Resistor	1 MΩ	±	5%	0,33 W	26351–140
R48	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R49	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R50	Resistor	10 kΩ	±	5%	0,33 W	26351–108
R51	Resistor	100 kΩ	±	5%	0,33 W	26834–650
R52	Resistor	68 kΩ	±	5%	0,33 W	26351–128
R53	Resistor	1 MΩ	±	5%	0,33 W	26351–140

Circuit Reference	Description				Part No.
C1	Capacitor	100 pF	± 2%	63 V	27888–801
C2	Capacitor	100 pF	± 2%	63 V	27888–801
C3	Capacitor	22 pF	± 2%	63 V	27888–794
C4	Capacitor	0,1 µF	+ 50% - 20%	30 V	27888–798
C5	Capacitor	100 pF	± 2%	63 V	27888–801
C6	Capacitor	0,1 µF	+ 50% - 20%	30 V	27888–798
C7	Capacitor	0,1 µF	+ 50% - 20%	30 V	27888–798
C8	Capacitor	15 nF	± 5%	160 V	27889–497
C9	Capacitor	15 nF	± 5%	160 V	27889–497
C10	Capacitor	15 nF	± 5%	160 V	27889–497
C11	Capacitor	1 µF	± 5%	63 V	27889–493
D1	Diode	1N4148			28433–801
D2	Diode	1N4148			28433–801
D3	Diode	1N4148			28433–801
D4	Diode	1N4148			28433–801
D5	Diode	1N4148			28433–801
D6	Diode	1N4148			28433–801
TR1	Transistor	BC213			28534–844
TR2	Transistor	BC213			28534–844
TR3	Transistor	BC213			28534–844
TR4	Transistor	BC213			28534–844
TR5	Transistor	BC213			28534–844
TR6	Transistor	BC213			28534–844
TR7	Transistor	BC213			28534–844
TR8	Transistor	BC213			28534–844
IC1	Integrated circuit 4011				20000–011
IC2	Integrated circuit 4027				20000–027
IC3	Integrated circuit 4011				20000–011
IC4	Integrated circuit 4027				20000–027
IC5	Integrated circuit 4011				20000–011
IC6	Integrated circuit 4001				20000–001
IC7	Integrated circuit 4001				20000–001
IC8	Integrated circuit 4027				20000–027
IC9	Integrated circuit 4050				20000–050
IC10	Integrated circuit 4011				20000–011
IC11	Integrated circuit 4011				20000–011
IC12	Integrated circuit 4029				20000–029
IC13	Integrated circuit 4028				20000–028
IC14	Integrated circuit 4001				20000–001
IC15	Integrated circuit 4016				20000–016
IC16	Integrated circuit 4016				20000–016
IC17	Integrated circuit 4001				20000–001
IC18	Integrated circuit 4011				20000–011
IC19	Integrated circuit 4011				20000–011
IC20	Integrated circuit 4027				20000–027
IC21	Integrated circuit 4001				20000–001
IC22	Integrated circuit 4011				20000–011
IC23	Integrated circuit 4027				20000–027
IC24	Integrated circuit 4001				20000–001

9.9 Ranging Amplifier Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed circuit board assembly				6330–323
R1	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R2	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R3	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R4	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R5	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R6	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R8	Resistor	10 kΩ	± 0,3%		26835–902
R9	Resistor	1,29 kΩ	± 0,5%		26835–903
R10	Potentiometer	100 kΩ	± 10%	0,75 W	27889–521
R11	Resistor	10 kΩ	± 0,3%		26835–902
R12	Resistor	105 Ω	± 0,5%		26835–904
R13	Potentiometer	10 kΩ	± 10%	0,75 W	27889–519
R14	Printed resistor	10 Ω			6131–064
R15	Resistor	91,4 Ω	± 0,5%		26835–905
R16	Potentiometer	20 kΩ	± 10%	0,75 W	27889–520
R17	Resistor	914 Ω	± 0,5%		26835–906
R18	Potentiometer	200 kΩ	± 10%	0,75 W	27889–522
R19	Resistor	9,9 kΩ	± 0,5%		26835–907
R20	Resistor	10 kΩ	± 0,3%		26835–902
R21	Resistor	10 kΩ	± 0,3%		26835–902
R22	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R23	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R24	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R25	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R26	Resistor	56 Ω	± 5%	0,33 W	26835–178
R27	Resistor	15 kΩ	± 5%	0,33 W	26351–115
R28	Resistor	27 kΩ	± 5%	0,33 W	26351–123
R29	Potentiometer	10 kΩ	± 20%	0,25 W	27284–697
R30	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R31	Resistor	15 kΩ	± 5%	0,33 W	26351–115
R32	Resistor	56 Ω	± 5%	0,33 W	26835–178
R33	Resistor	2,2 Ω	± 5%	0,33 W	26835–901
R34	Resistor	2,2 Ω	± 5%	0,33 W	26835–901
R35	Resistor	1 kΩ	± 5%	0,33 W	26351–090
R36	Resistor	1MΩ	± 5%	0,33 W	26351–140
R37	Resistor	1MΩ	± 5%	0,33 W	26351–140
R38	Resistor	10 MΩ	± 10%	0,33 W	26341–820
R39	Resistor	10 MΩ	± 10%	0,33 W	26341–820
R40	Resistor	10 MΩ	± 10%	0,33 W	26341–820
R41	Resistor	10 MΩ	± 10%	0,33 W	26341–820
R42	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R43	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R44	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R45	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R46	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R47	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R48	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R49	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R50	Resistor	220 Ω	± 5%	0,33 W	26351–075
R51	Resistor	5,6 Ω	± 2%	0,5 W	26834–401
R52	Resistor	5,6 Ω	± 2%	0,5 W	26834–401
R53	Resistor	220 Ω	± 5%	0,33 W	26351–075
R54	Resistor	10 kΩ	± 0,5%		26835–185
R55	Resistor	10 kΩ	± 0,5%		26835–185
R56	Resistor	100 kΩ	± 0,3%		26835–781

Circuit Reference	Description				Part No.
R57	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R58	Resistor	9,9 kΩ	± 0,5%		26835–907
R59	Resistor	30 kΩ	± 2%	0,5 W	26834–490
R60	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R61	Resistor	10 MΩ	± 10%	0,33 W	26341–820
R62	Resistor	90 kΩ	± 0,5%		26835–908
R63	Resistor	270 kΩ	± 2%	0,5 W	26834–513
R64	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R65	Potentiometer	200 Ω	± 10%	0,75 W	27889–514
R66	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R67	Potentiometer	5 kΩ	± 10%	0,75 W	27889–518
R68	Potentiometer	200 Ω	± 10%	0,75 W	27889–514
R69	Resistor	33 kΩ	± 5%	0,33 W	26351–124
R70	Resistor	33 kΩ	± 5%	0,33 W	26351–124
R71	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R72	Resistor	100 Ω	± 5%	0,33 W	26351–055
C1	Capacitor	10 µF		16 V	27888–796
C2	Capacitor	10 µF		16 V	27888–796
C3	Capacitor	0,1 µF	+ 50% - 20%	30 V	27888–798
C4	Capacitor	330 pF			27888–806
C5	Capacitor	47 pF	± 2%	63 V	27889–006
C6	Capacitor	10 µF		16 V	27888–796
C7	Capacitor	0,1 µF	+ 50% - 20%	30 V	27888–798
C8	Capacitor	330 pF			27888–806
C9	Capacitor	0,15 µF	± 5%	100 V	27889–498
C10	Capacitor	10 µF		16 V	27888–796
C11	Capacitor	1 nF	± 20%		27889–507
C12	Capacitor	10 µF		16 V	27888–796
C13	Capacitor	10 µF		16 V	27888–796
C14	Capacitor	22 pF	± ¼pF	63 V	27888–794
C15	Capacitor	47 pF	± 2%	63 V	27889–006
C16	Capacitor	100 pF	± 2%	63 V	27888–801
C17	Capacitor	100 pF	± 2%	63 V	27888–801
C18	Capacitor	220 pF	± 2%	63 V	27889–386
C19	Capacitor	4,7 pF	± ¼pF	63 V	27888–809
C20	Capacitor	4,7 pF	± ¼pF	63 V	27888–809
C21	Capacitor	15 pF	± 2%	63 V	27889–491
D1	Diode	1N4148			28433–801
D2	Diode	1N4148			28433–801
D3	Diode	1N5338 or 5Zs5.1B			28863–114
D4	Diode	1N5338 or 5Zs5.1B			28863–114
D5	Diode	1N4148			28433–801
D6	Diode	1N4148			28433–801
D7	Diode	1N4148			28433–801
D8	Diode	1N4148			28433–801
D9	Diode	1N4148			28433–801
D10	Diode	1N4148			28433–801
TR1	Transistor	BC183			28554–842
TR2	Transistor	BC183			28554–842
TR3	Transistor	BC183			28554–842
TR4	Transistor	BC183			28554–842
TR5	Transistor	BC183			28554–842
TR6	Transistor	E112			28862–846
TR7	Transistor	E108			28863–108
TR8	Transistor	E112			28862–846

Circuit Reference	Description		Part No.
TR9	Transistor	E108	28863–108
TR10	Transistor	E112	28862–846
TR11	Transistor	E108	28863–108
TR12	Transistor	E108	28863–108
TR13	Transistor	E105	28863–109
TR14	Transistor	E105	28863–109
TR15	Transistor	E108	28863–108
TR16	Transistor	E108	28863–108
TR17	Transistor	E108	28863–108
TR18	Transistor	E108	28863–108
TR19	Transistor	E105	28863–109
TR20	Transistor	BC183	28554–842
TR21	Transistor	BC213	28534–844
TR22	Transistor	2N2905A	28862–861
TR23	Transistor	BC183	28554–842
TR24	Transistor	2N3053	28862–842
TR25	Transistor	E105	28863–109
TR26	Transistor	E105	28863–109
TR27	Transistor	E108	28863–108
TR28	Transistor	E112	28862–846
TR29	Transistor	E112	28862–846
TR30	Transistor	BC213	28534–844
TR31	Transistor	E112	28862–846
TR32	Transistor	E112	28862–846
TR33	Transistor	BC183	28554–842
TR34	Transistor	BC213	28534–844
TR35	Transistor	E112	28862–846
TR36	Transistor	E112	28862–846
TR37	Transistor	BC183	28554–842
TR38	Transistor	BC183	28554–842
TR39	Transistor	BC183	28554–842
TR40	Transistor	BC183	28554–842
TR41	Transistor	E112	28862–846
TR42	Transistor	E112	28862–846
TR43	Transistor	BC183	28554–842
TR44	Transistor	E108	28863–108
TR45	Transistor	E112	28862–846
TR46	Transistor	E112	28862–846
TR47	Transistor	E112	28862–846
TR48	Transistor	BC183	28554–842
IC1	Integrated circuit 4001		20000–001
IC2	Integrated circuit 4011		20000–011
IC3	Integrated circuit 4069		20000–069
IC4	Operational amplifier 100 MHz G.B.W.		28863–110
IC5	Integrated circuit LF355		28863–145
IC6	Integrated circuit LF355		28863–145
IC7	Integrated circuit 4011		20000–011
IC8	Integrated circuit 741C		28862–856
IC9	Operational amplifier 100 MHz G.B.W.		28863–110
IC10	Integrated circuit 741C		28862–856
IC11	Integrated circuit 741C		28862–856

9.10 Phase Sensitive Detector Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed circuit board assembly				6330–324
R1	Resistor	6,8 kΩ	± 5%	0,33 W	26351–105
R2	Potentiometer	2 kΩ	± 10%	0,75 W	27889–517
R3	Resistor	99 kΩ	± 0,5%		26835–895
R4	Resistor	1 MΩ	± 1%		26835–133
R5	Resistor	6,8 kΩ	± 5%	0,33 W	26351–105
R6	Potentiometer	2 kΩ	± 10%	0,75 W	27889–517
R7	Resistor	99 kΩ	± 0,5%		26835–895
R8	Resistor	1 MΩ	± 1%		26835–133
R9	Resistor	6,8 kΩ	± 5%	0,33 W	26351–105
R10	Resistor	220 Ω	± 5%	0,33 W	26351–075
R11	Resistor	50 kΩ	± 0,5%		26835–896
R12	Resistor	500 kΩ	± 1%		26835–897
R13	Resistor	390 Ω	± 5%	0,33 W	26351–080
R14	Resistor	100 kΩ	± 1%		26835–079
R15	Resistor	10 kΩ	± 0,5%		26835–185
R16	Resistor	10 kΩ	± 0,5%		26835–185
R17	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R18	Resistor	16 kΩ	± 0,5%		26835–898
R19	Resistor	16 kΩ	± 0,5%		26835–898
R20	Potentiometer	1 kΩ	± 20%	0,25 W	27113–987
R21	Resistor	13,8 kΩ	± 0,5%		26835–899
R22	Potentiometer	470 Ω	± 20%	0,25 W	27284–748
R23	Resistor	8,7 kΩ	± 5%		26835–900
R24	Resistor	220 Ω	± 5%	0,33 W	26351–075
R25	Resistor	2,2 kΩ	± 5%	0,33 W	26351–095
R26	Potentiometer	2 kΩ	± 10%	0,75 W	27889–517
R27	Resistor	4,7 kΩ	± 5%	0,33 W	26351–101
R28	Resistor	10 kΩ	± 0,5%		26835–185
R29	Resistor	10 kΩ	± 0,5%		26835–185
R30	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R31	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R32	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R33	Resistor	56 Ω	± 5%	0,33 W	26835–178
R34	Potentiometer	500 kΩ	± 10%	0,75 W	27889–523
R35	Potentiometer	500 kΩ	± 10%	0,75 W	27889–523
R36	Resistor	270 kΩ	± 2%	0,5 W	26834–513
R37	Resistor	270 kΩ	± 2%	0,5 W	26834–513
R38	Resistor	1 kΩ	± 5%	0,33 W	26351–090
R39	Resistor	220 kΩ	± 5%	0,33 W	26351–134
R40	Resistor	220 kΩ	± 5%	0,33 W	26351–134
R41	Resistor	1 kΩ	± 5%	0,33 W	26351–090
R42	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R43	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R44	Resistor	13,8 kΩ	± 0,5%		26835–899
R45	Resistor	8,7 kΩ	± 0,5%		26835–900
R46	Resistor	10 Ω	± 5%	0,33 W	26834–706
R47	Resistor	10 Ω	± 5%	0,33 W	26834–706
R48	Resistor	1 MΩ	± 5%	0,33 W	26351–140
R49	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R50	Resistor	270 Ω	± 5%	0,33 W	26351–077
R51	Resistor	270 Ω	± 5%	0,33 W	26351–077
R52	Resistor	10 kΩ	± 5%	0,33 W	26351–108
R53	Potentiometer	10 kΩ	± 20%	0,25 W	27284–697
R56	Resistor	10 MΩ	± 10%	0,33 W	26341–820

Circuit Reference	Description				Part No.
C1	Capacitor	10 µF		16 V	27888–796
C2	Capacitor	10 µF		16 V	27888–796
C3	Capacitor	10 µF		16 V	27888–796
C4	Capacitor	2 nF	± 0,5%		27889–510
C5	Capacitor	200 pF	± 1%		27889–511
C6	Capacitor	3,3 nF	± 20%		27889–496
C8	Capacitor	47 pF	± 2%	63 V	27889–006
C9	Capacitor	100 µF		3 V	27889–061
C10	Capacitor	100 µF		3 V	27889–061
C11	Capacitor	4,7 µF	± 20%		27889–495
C12	Capacitor	1 µF	± 5%		27889–493
C13	Capacitor	6,8 nF	± 20%	160 V	27889–509
C14	Capacitor	100 nF	+ 50% - 20%		27888–798
C15	Capacitor	100 nF	+ 50% - 20%		27888–798
C16	Capacitor	100 nF	+ 50% - 20%		27888–798
C17	Capacitor	100 nF	+ 50% - 20%		27888–798
C18	Capacitor	100 nF	+ 50% - 20%		27888–798
C19	Capacitor	33 nF	± 20%	250 V	27889–536
C20	Capacitor	4,7 µF	± 20%		27889–495
C21	Capacitor	470 nF	± 5%	100 V	27889–505
C22	Capacitor	10 µF		16 V	27888–796
C23	Capacitor	10 µF		16 V	27888–796
C24	Capacitor	10 nF	+ 50% - 25%	25 V	27889–538
C25	Capacitor	10 nF	+ 50% - 25%	25 V	27889–538
D1	Diode	1N4148			28433–801
D2	Diode	1N4148			28433–801
D3	Diode	BZY88C10V			28862–932
D4	Diode	1N4148			28433–801
D5	Diode	1N4148			28433–801
TR1	Transistor	E112			28862–846
TR2	Transistor	E112			28862–846
TR3	Transistor	E112			28862–846
TR4	Transistor	E114			28863–107
TR5	Transistor	E114			28863–107
TR6	Transistor	E114			28863–107
TR7	Transistor	E114			28863–107
TR8	Transistor	E114			28863–107
TR9	Transistor	E114			28863–107
TR10	Transistor	E114			28863–107
TR11	Transistor	E114			28863–107
TR12	Transistor	E114			28863–107
TR13	Transistor	E114			28863–107
TR14	Transistor	E112			28862–846
TR15	Transistor	E112			28862–846
TR16	Transistor	E112			28862–846

Circuit Reference	Description		Part No.
TR17	Transistor	E112	28862–846
TR18	Transistor	E112	28862–846
TR19	Transistor	E112	28862–846
TR20	Transistor	E112	28862–846
TR21	Transistor	E112	28862–846
TR22	Transistor	E112	28862–846
TR23	Transistor	E112	28862–846
TR24	Transistor	E114	28863–107
TR25	Transistor	E114	28863–107
TR26	Transistor	E114	28863–107
TR27	Transistor	E114	28863–107
TR28	Transistor	E112	28862–846
TR29	Transistor	E112	28862–846
TR30	Transistor	E112	28862–846
TR31	Transistor	E112	28862–846
TR32	Transistor	E112	28862–846
TR33	Transistor	E112	28862–846
TR34	Transistor	E114	28863–107
TR35	Transistor	E114	28863–107
TR36	Transistor	BC183	28554–842
TR37	Transistor	E114	28863–107
TR38	Transistor	E114	28863–107
TR39	Transistor	E114	28863–107
IC1	Operational amplifier 100 MHz G.B.W.		28863–110
IC2	Integrated circuit LF355		28863–145
IC3	Integrated circuit CA3140 T		28863–115
IC4	Integrated circuit LM 311 N		28863–112
IC5	Integrated circuit 4011		20000–011
IC6	Integrated circuit 4001		20000–001
IC7	Integrated circuit CA3140 T		28863–115
IC8	Integrated circuit 741C		28862–853
IC9	Integrated circuit 741C		28862–853
IC10	Integrated circuit 4011		20000–011
IC11	Integrated circuit 4011		20000–011
L1	Inductor assembly		6131–082

9.11 Control Logic Printed Circuit Board

Circuit Reference	Description				Part No.
	Printed circuit board assembly				6330–322
R1	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R2	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R3	Resistor	100 kΩ	± 5%	0,33 W	28634–650
R4	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R5	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R6	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R7	Resistor	100 kΩ	± 5%	0,33 W	26834–650
R8	Resistor	15 kΩ	± 5%	0,33 W	26351–115
C1	Capacitor	0,1 μF	+ 50% - 20%	30 V	27888–798
C2	Capacitor	22 pF	± 0,25 pF	63 V	27888–794
C3	Capacitor	100 pF	± 2%	63 V	27888–801
C4	Capacitor	22 pF	± 0,25 pF	63 V	27888–794
D1	Diode	1N4148			28433–801
IC1	Integrated circuit 4001				20000–001
IC2	Integrated circuit 4011				20000–011
IC3	Integrated circuit 4011				20000–011
IC4	Integrated circuit 4001				20000–001
IC5	Integrated circuit 4011				20000–011
IC6	Integrated circuit 4011				20000–011
IC7	Integrated circuit 4011				20000–011
IC8	Integrated circuit 4027				20000–027
IC9	Integrated circuit 4001				20000–001
IC10	Integrated circuit 4001				20000–001
IC11	Integrated circuit 4027				20000–027
IC12	Integrated circuit 4001				20000–001
IC13	Integrated circuit 4001				20000–001
IC14	Integrated circuit 4001				20000–001
IC15	Integrated circuit 4027				20000–027
IC16	Integrated circuit 4011				20000–011
IC17	Integrated circuit 4001				20000–001
IC18	Integrated circuit 4001				20000–001
IC19	Integrated circuit 4027				20000–027
IC20	Integrated circuit 4011				20000–011

Instrument Repairs and Spares

The manufacturer's joint service and spares organisation for SULLIVAN instruments.

LONDON INSTRUMENT REPAIR CENTRE

Spares and Repairs
Archcliffe Road,
Dover,
Kent CT17 9EN
England.
Tel: Dover (0304) 202620
Telex: 96283 LIRC

Repairs only
Cunnington Street,
Acton Lane Works,
Chiswick,
London, W4 5HJ
Tel: 01-995 9212
Telex: 22583 LIRC

Instruments may be delivered to either address. All Sullivan instruments returned for service will be re-calibrated at the Sullivan works before despatch.

SULLIVAN STANDARDS LABORATORY

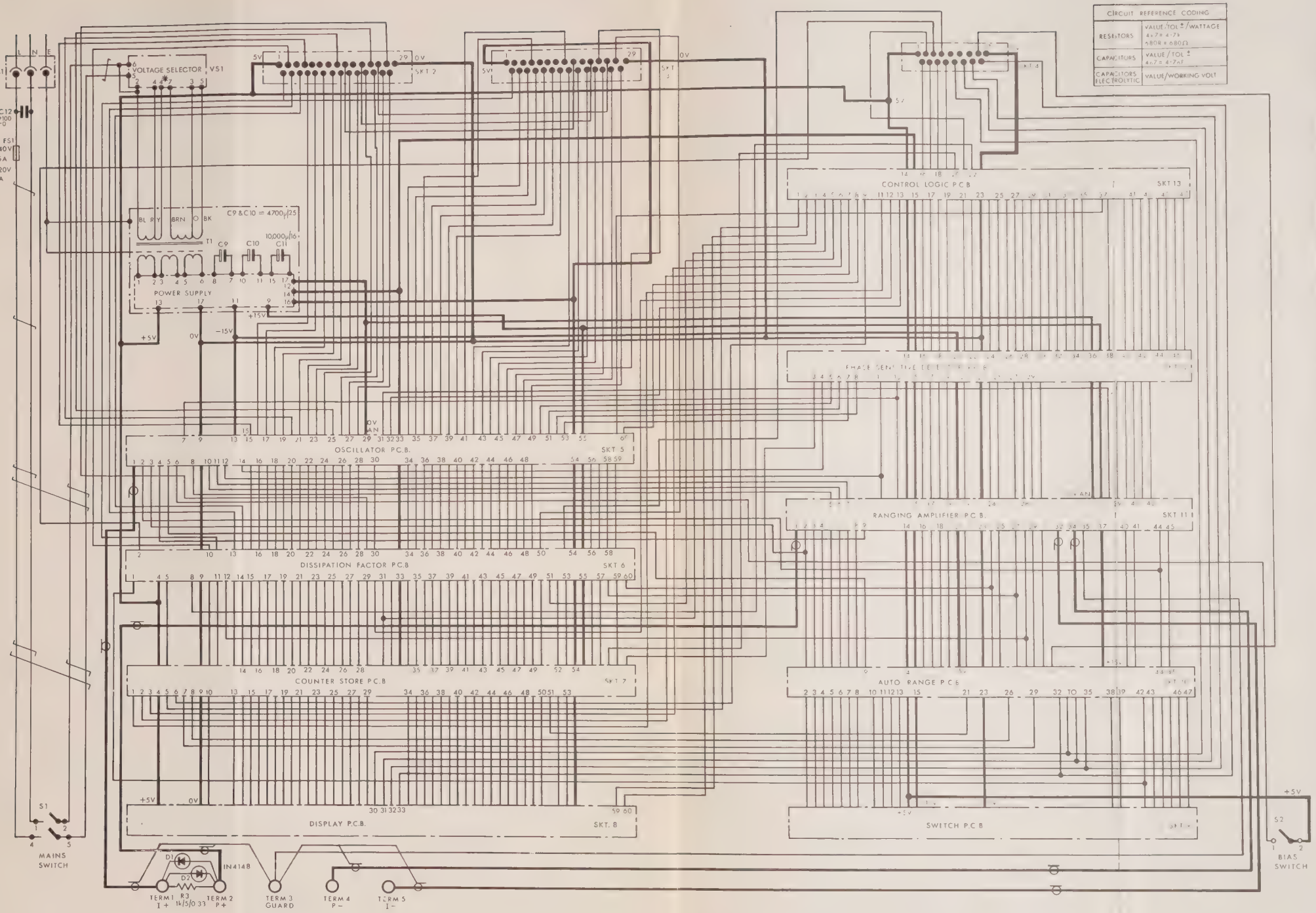
In cases where a BCS Certificate of Calibration is required, this calibration work will normally be carried out in the Sullivan Standards Laboratory at Dover (BCS Approval No. 0023). BCS certification is a chargeable service which should be specifically mentioned on the repair order issued by the owners of the instrument.

OVERSEAS

Owners of Sullivan instruments located outside Great Britain, should consult the Appointed Sullivan Distributor for their country regarding spares or return to L.I.R.C. for repairs and re-calibration.

If returning an instrument to Britain for repair, it should be sent freight pre-paid, to L.I.R.C. AT DOVER (not to the Chiswick Unit). A copy of the Invoice and the Packing Note should be sent simultaneously by airmail to L.I.R.C. at Dover to expedite clearance through the British Customs. A repair estimate, showing return freight and other charges will be submitted to the sender, if required, before work on the instrument commences.

SULLIVAN INSTRUMENTS ARE GUARANTEED FOR 12 MONTHS FROM THE DATE OF PURCHASE BY THE USER.

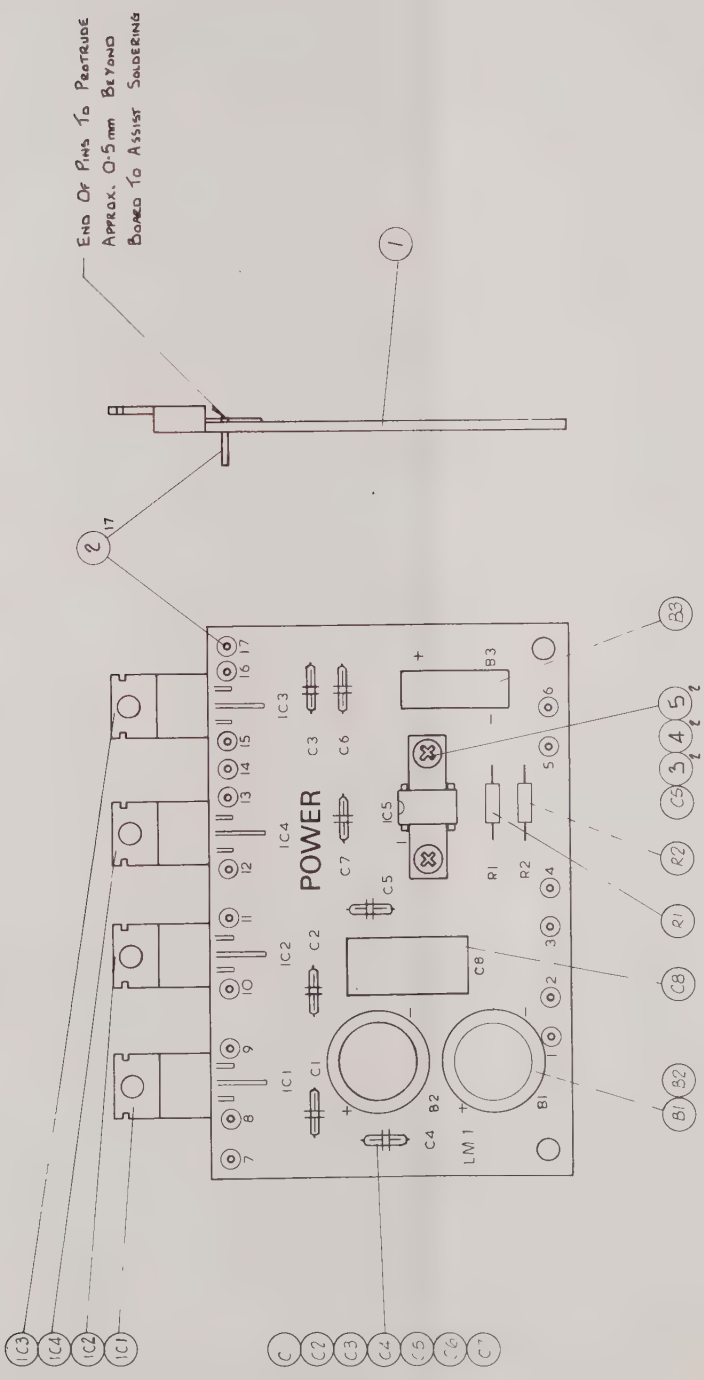


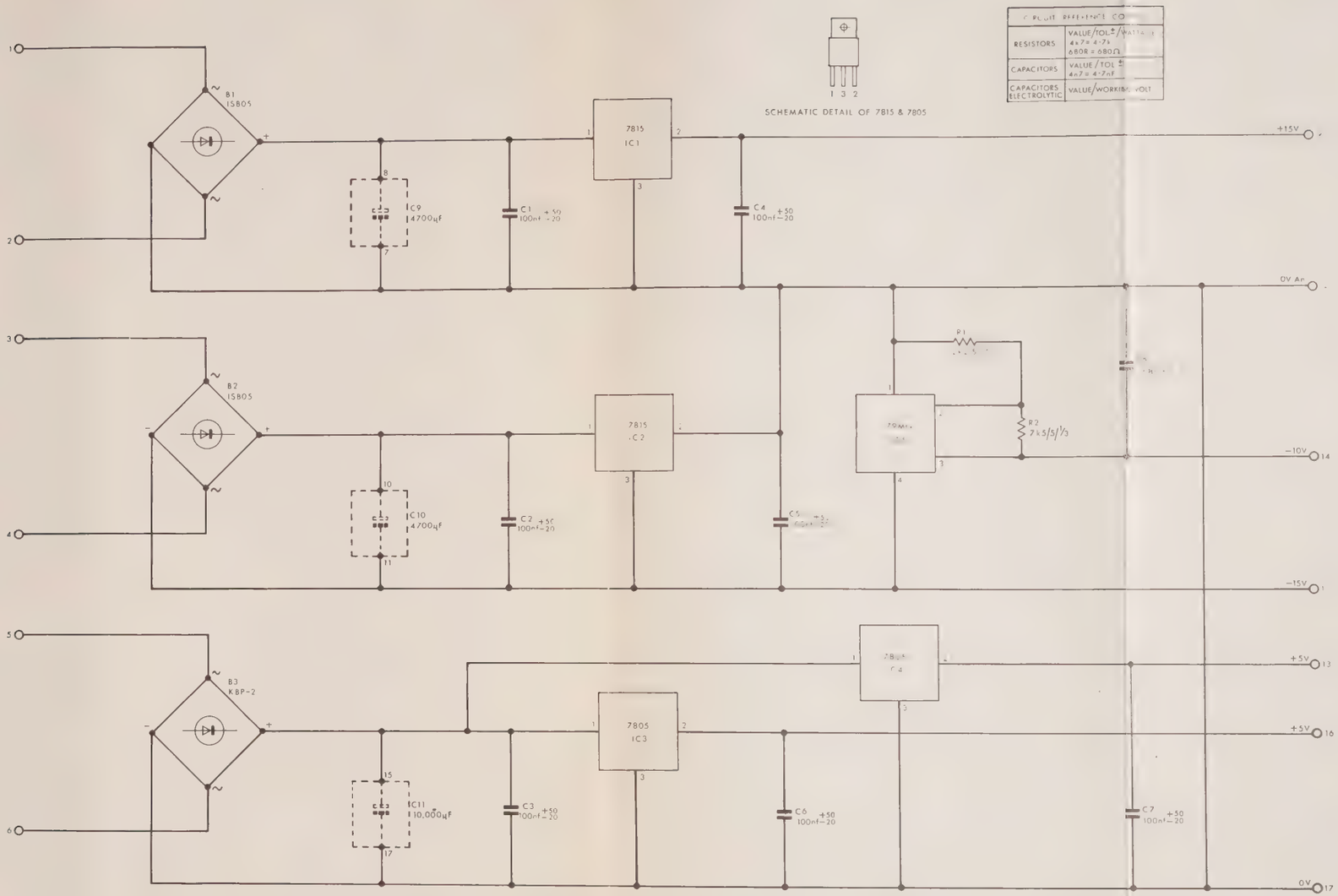
CIRCUIT REFERENCE CODING	
RESISTORS	VALUE/TOL ± / WATTAGE 4k7 = 4·7k 680R = 680Ω
CAPACITORS	VALUE / TOL ± 4n7 = 4·7nF
CAPACITORS ELECTROLYTIC	VALUE/WORKING VOLT

SOCKET 2	
PIN No	DESCRIPTION

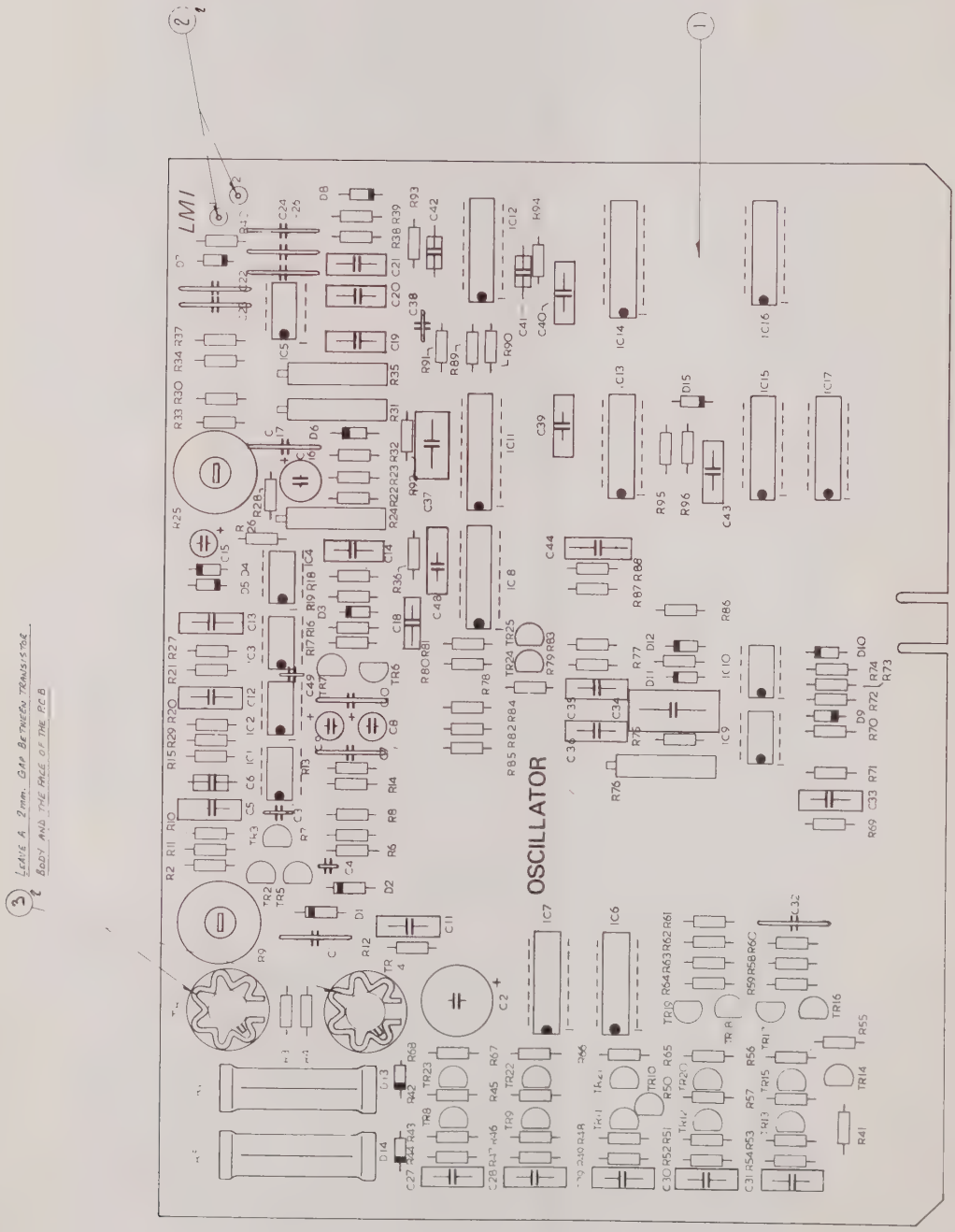
SOCKET 4	
	5 VOLT
2	C/G EXT FUNCTION I/P
3	R/S EXT I/P
4	4 EXT RANGE CODE I/P
5	D.F EXT I/P
6	2 EXT RANGE CODE I/P
7	D.F MODE O/P
8	1 EXT RANGE CODE I/P
10	1 RANGE CODE O/P
12	2 RANGE CODE O/P
14	4 RANGE CODE O/P
15	DATA READY
16	C/G FUNCTION O/P
17	0 VOLT
LINKS	SK2/17 TO SK3/17
	SK2/21 TO SK3/21

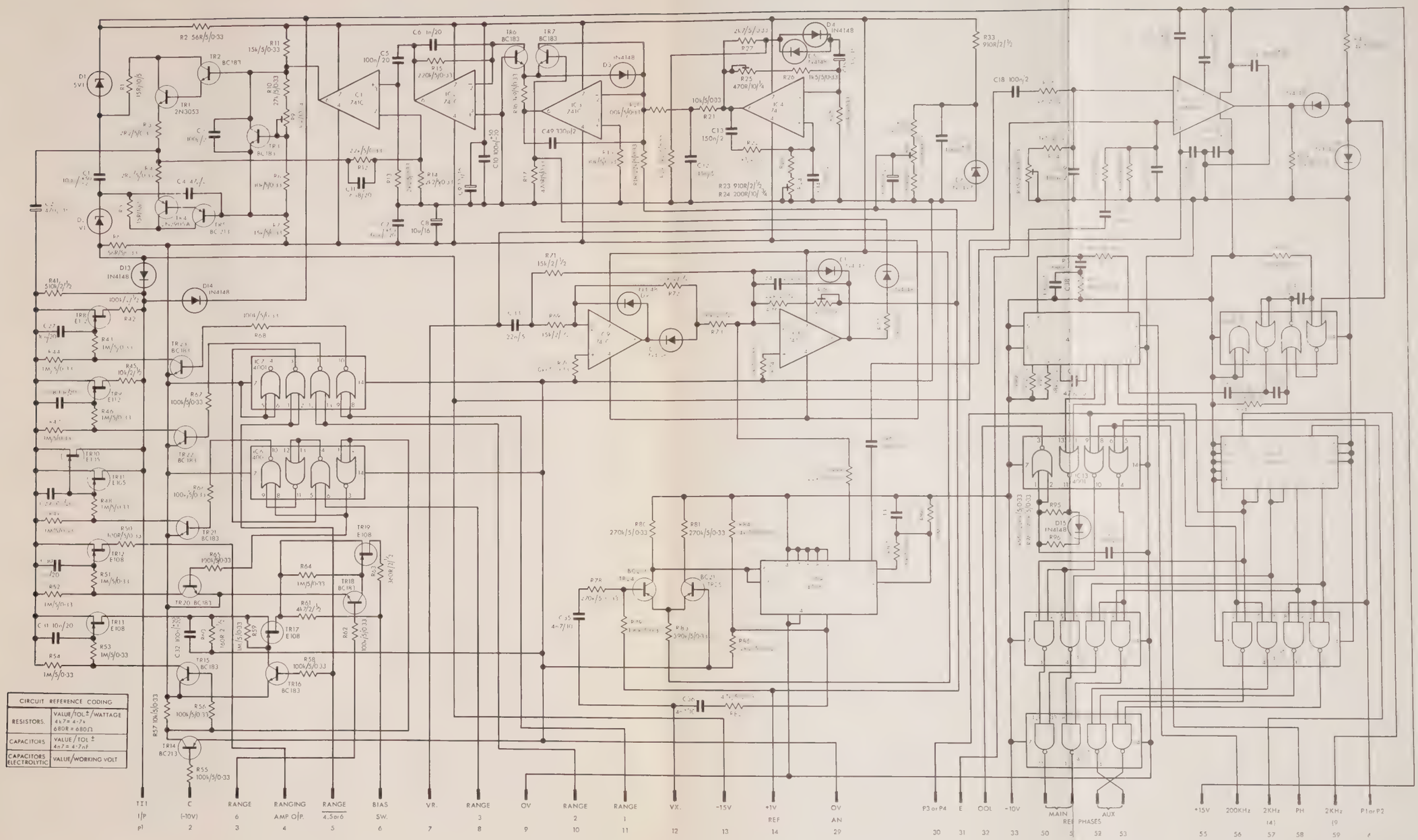
10.2 Power Supply Printed Circuit Board Lay-out



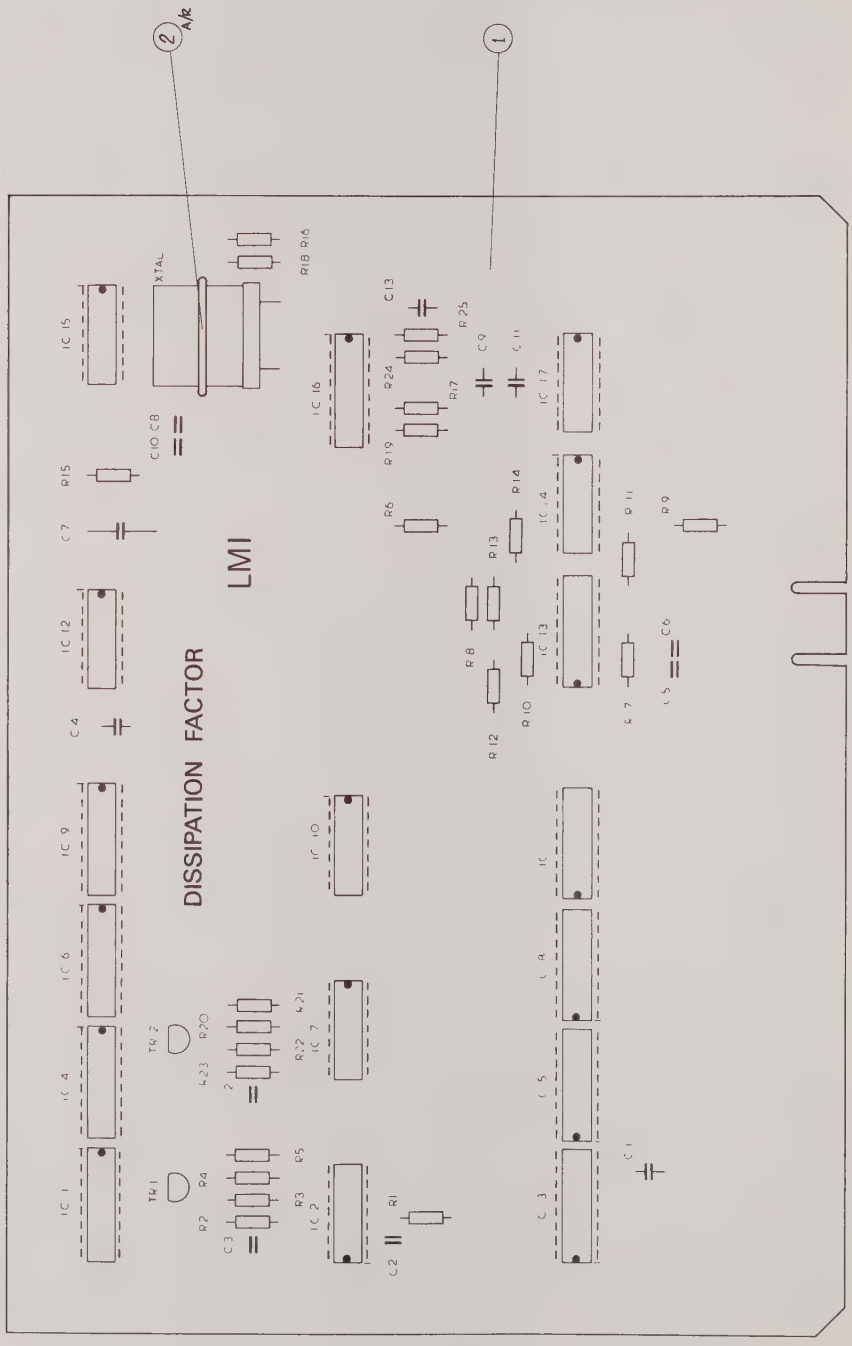

SCHEMATIC DETAIL OF 7815 & 7805
1 3 2
RESISTORS
CAPACITORS
CAPACITORS ELECTROLYTIC
B1 1580S
B2 1580S
B3 KBP-2
7815 IC1
7815 IC2
7805 IC3
C9 4700μF
C10 4700μF
C11 10,000μF
C1 100nf +50 -20
C2 100nf +50 -20
C3 100nf +50 -20
C4 100nf +50 -20
C6 100nf +50 -20
C7 100nf +50 -20
P1
R2 7k5/5/1/3
+15V
0V Ar
-10V
-15V
+5V
+5V
0V

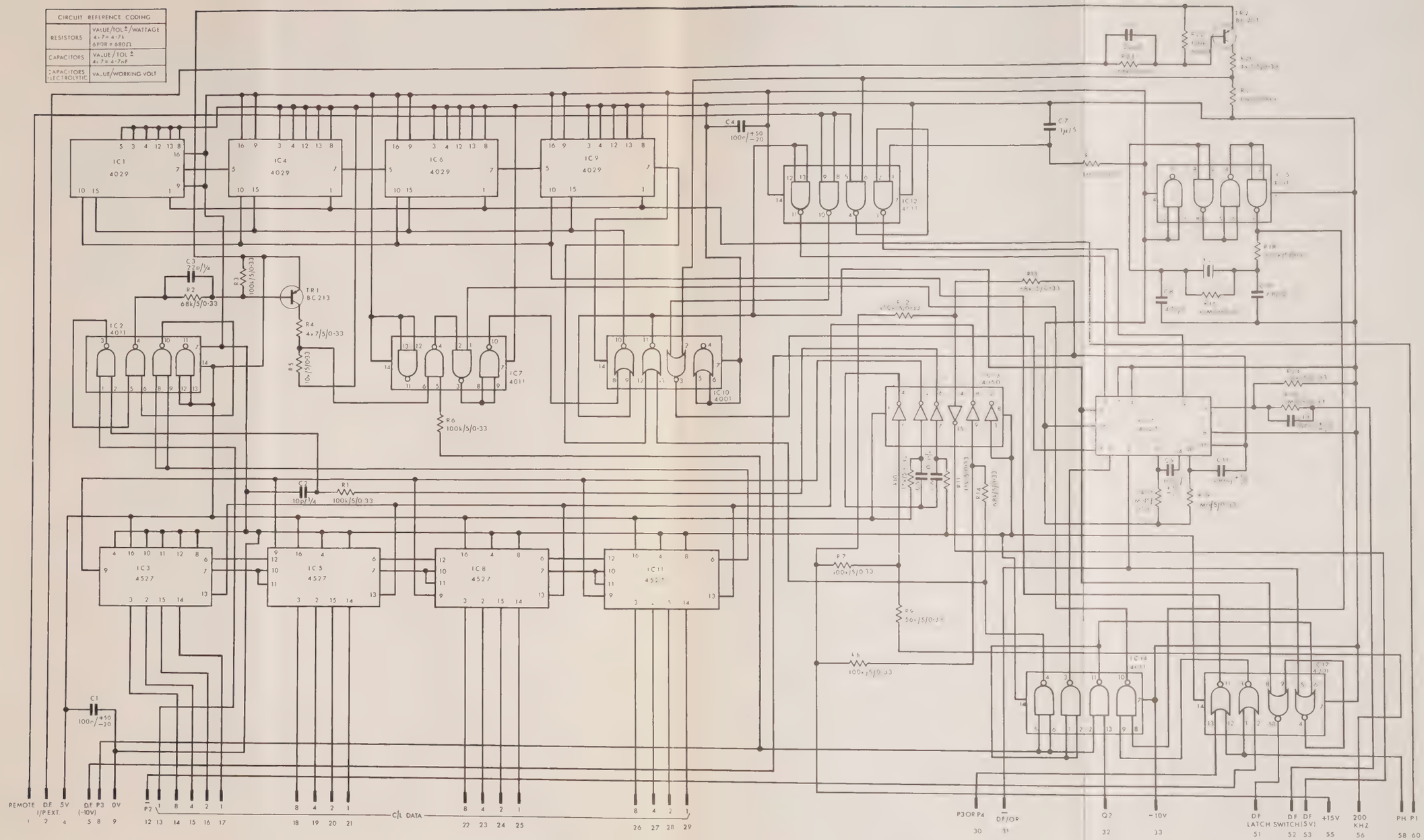
10.3 Oscillator Printed Circuit Board Lay-out



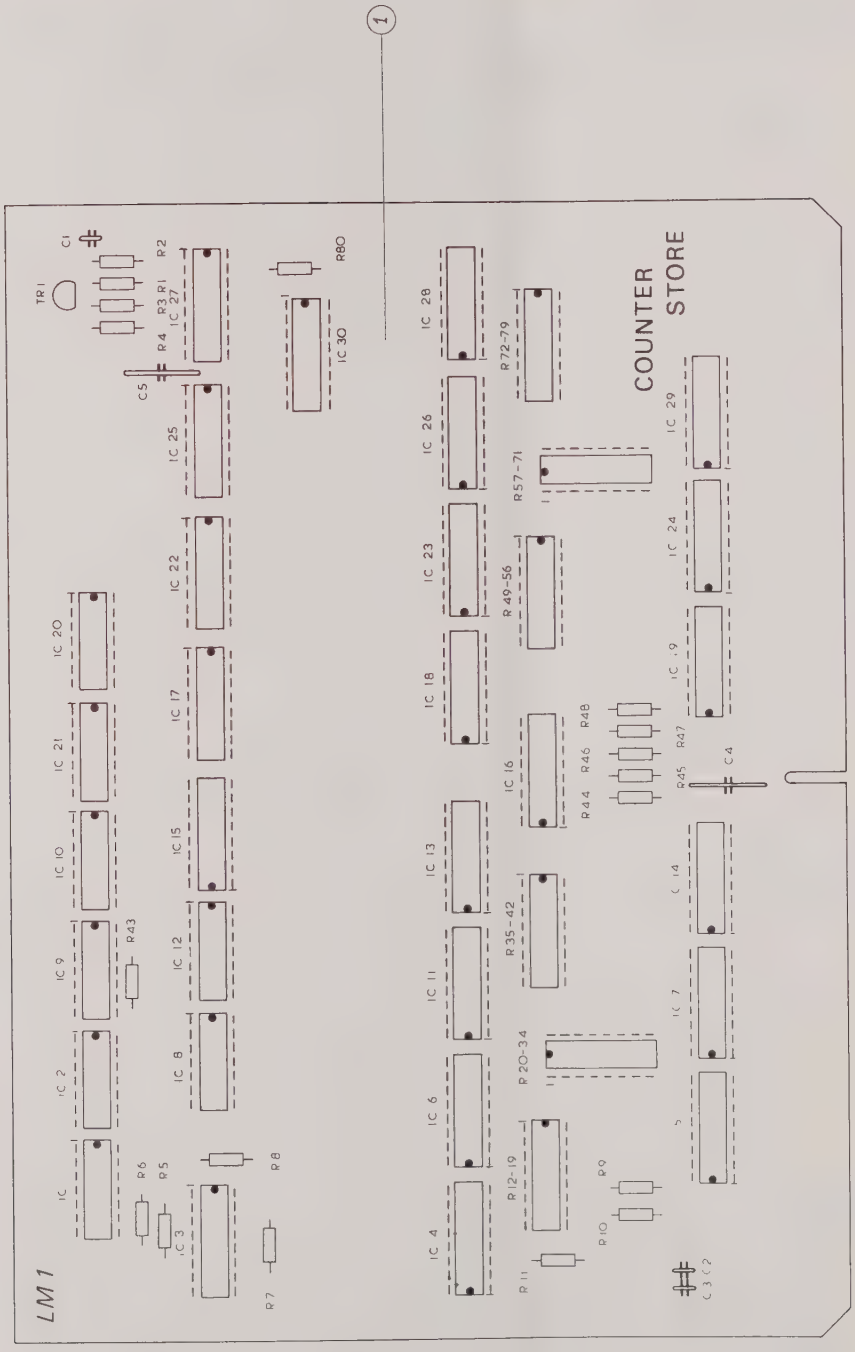

CIRCUIT REFERENCE CODING
RESISTORS: VALUE/TOL±/WATTAGE 4k7 = 4·7k 680R = 680Ω
CAPACITORS: VALUE/TOL± 4n7 = 4·7nF
CAPACITORS ELECTROLYTIC: VALUE/WORKING VOLT
TI1 I/P p1
C (-10V) 2
RANGE 6 3
RANGING AMP O/P. 4
RANGE 4,5 or 6 5
BIAS SW. 6
VR. 7
RANGE 3 8
OV 9
RANGE 2 10
RANGE 1 11
VX. 12
-15V 13
+1V REF 14
OV AN 29
P3 or P4 30
E 31
OOL 32
-10V 33
MAIN REF 50
PHASES 52
AUX 53
+15V 55
200KHz 56
2KHz (4) 57
PH 58
2KHz (9) 59
P1 or P2 6

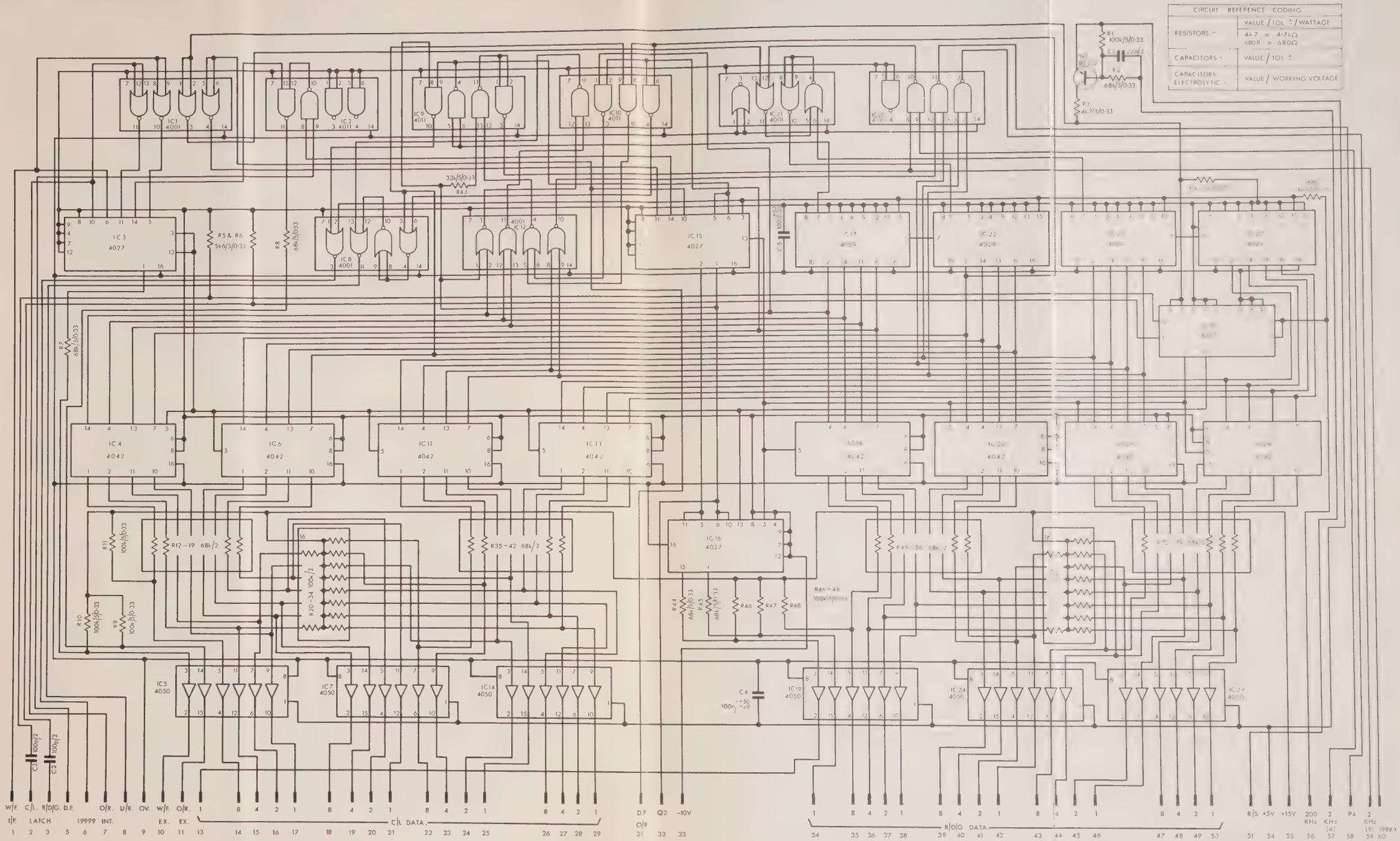
10.4 Dissipation Factor Printed Circuit Board Lay-out

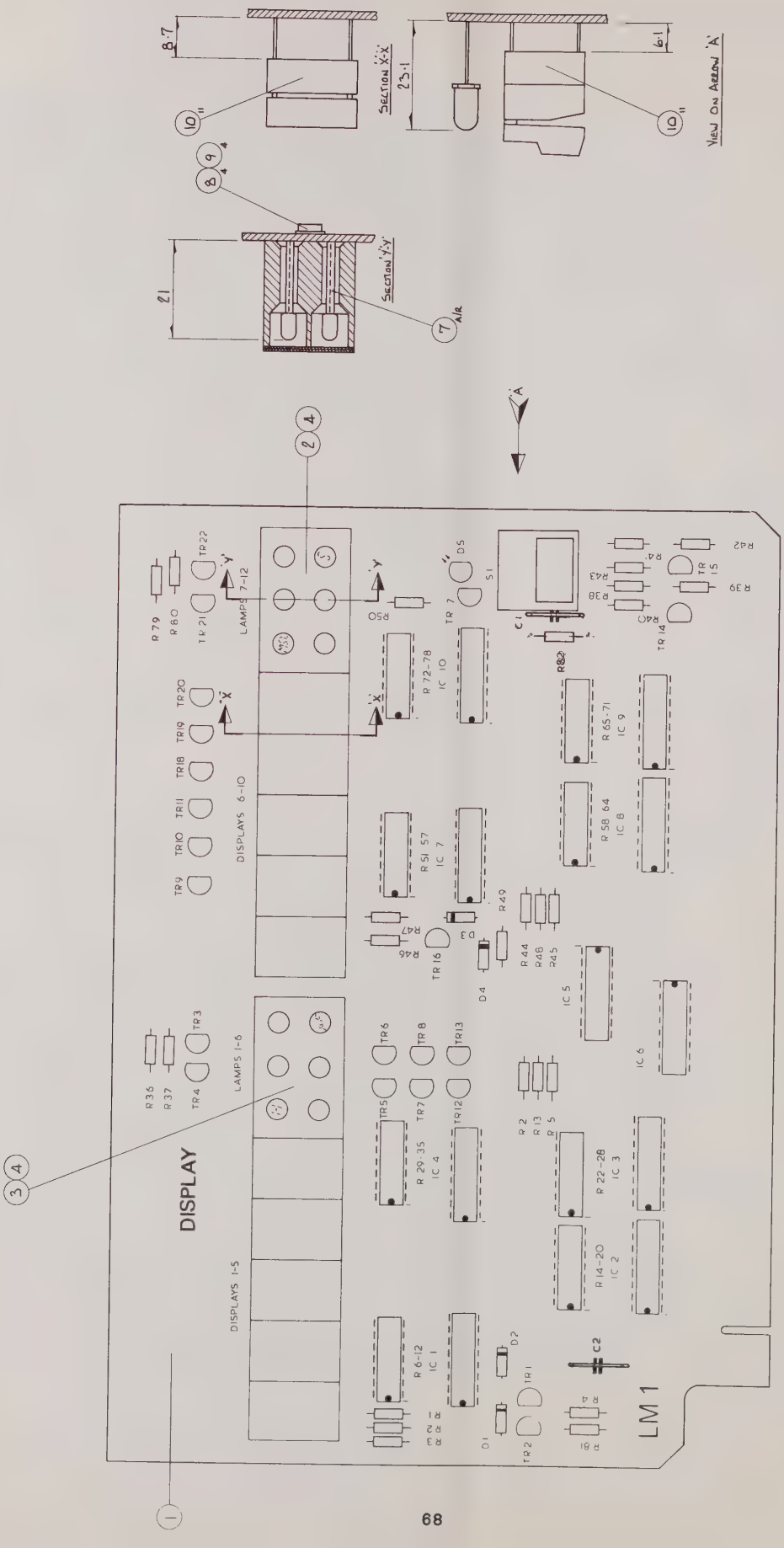


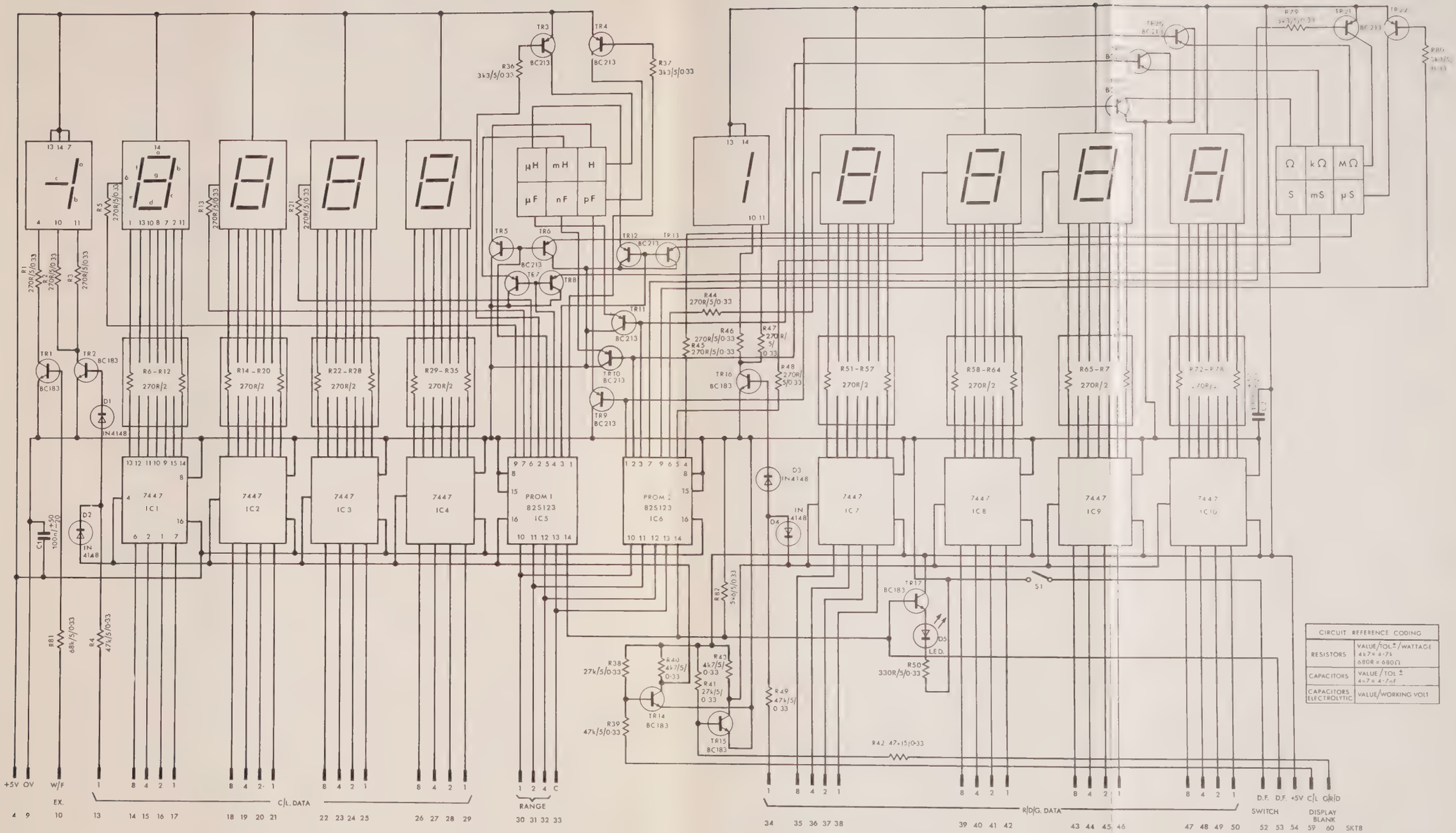

CIRCUIT REFERENCE CODING
RESISTORS
VALUE/TOL±/WATTAGE
4·7=4·7k
680R=680Ω
CAPACITORS
VALUE/TOL±
4·7=4·7nF
CAPACITORS (ELECTROLYTIC)
VALUE/WORKING VOLT
IC1 4029
IC4 4029
IC6 4029
IC9 4029
IC12 4011
IC2 4011
IC7 4011
IC10 4001
IC3 4527
IC5 4527
IC8 4527
IC11 4527
IC14 4011
IC15 4011
C1 100n/+50 −20
C2 10p/1/4
C3 22p/1/4
C4 100n/+50 −20
C7 1µ/5
R1 100k/5/0·33
R2 68k/5/0·33
R3 470k/100
TR1 BC213
R4 4·7/5/0·33
R5 10k/5/0·33
R6 100k/5/0·33
R7 100k/5/0·33
R9 56k/5/0·33
R16 100k/5/0·33
R18
R13
R14 47k/5/0·33
C5
C6
C8
C10
C11
REMOTE 1
DF 1/P EXT. 2
5V 4
DF P3 (−10V) 5 8
0V 9
P2 12 13 14 15 16 17
C/L DATA
8 4 2 1 18 19 20 21
8 4 2 1 22 23 24 25
8 4 2 1 26 27 28 29
P3 OR P4 30
DF/OR 31
Q2 32
−10V 33
DF LATCH 51
DF SWITCH (5V) 52 53
+15V 55
200 KHZ 56
PH P1 58 60

10.5 Counter / Store Printed Circuit Board Lay-out

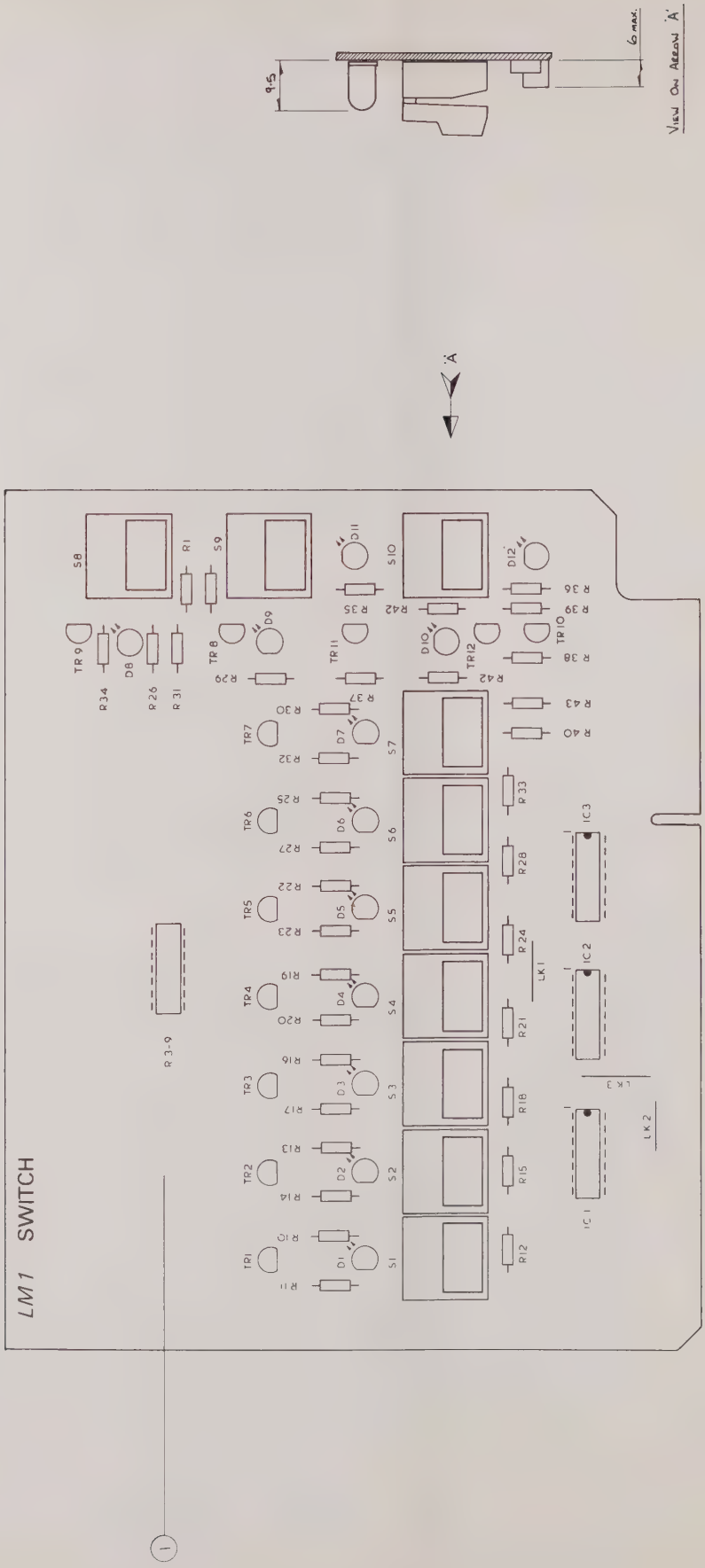


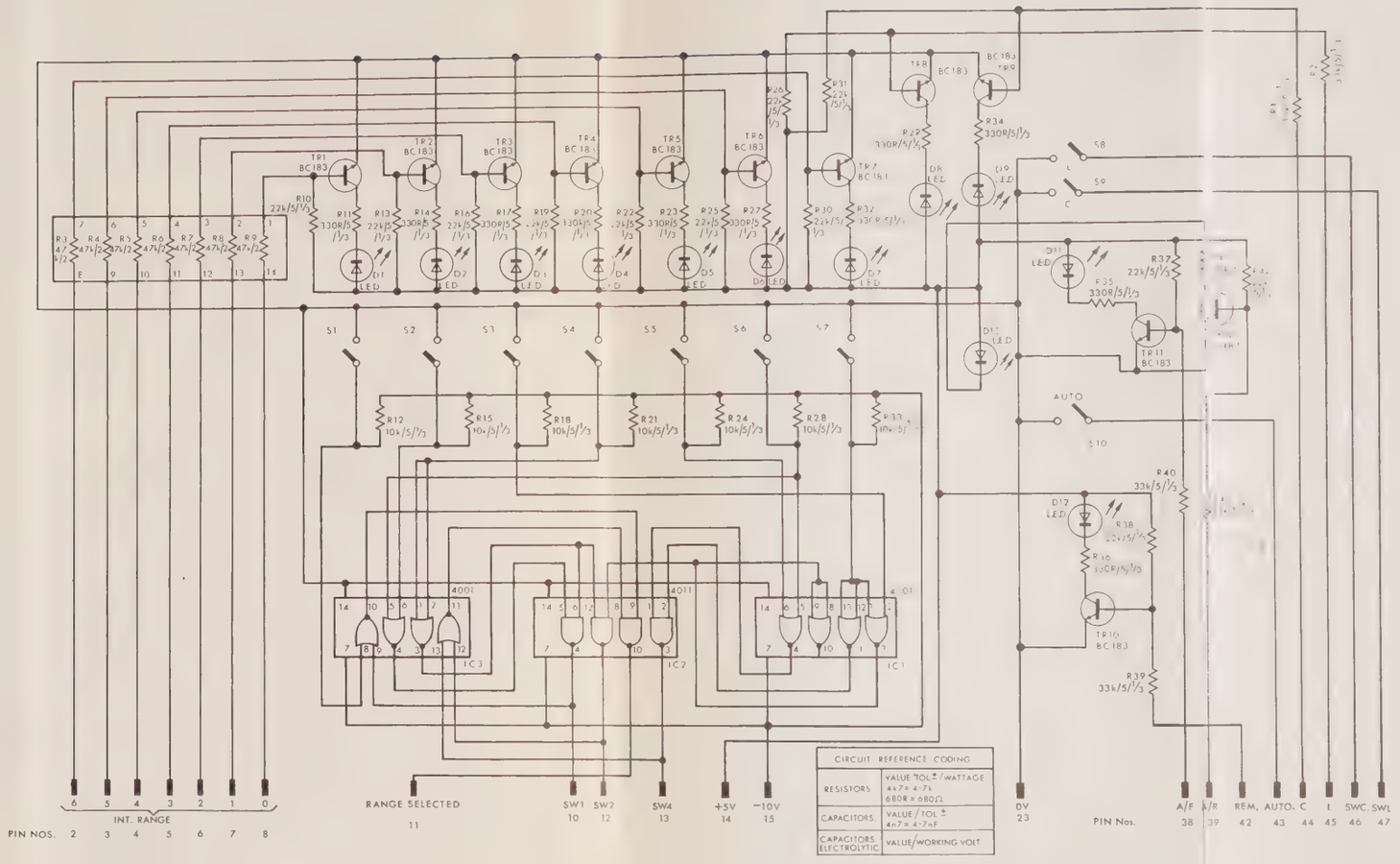

CIRCUIT REFERENCE CODING
RESISTORS – VALUE / TOL ± / WATTAGE
4k7 = 4·7kΩ
680R = 680Ω
CAPACITORS – VALUE / TOL ±
CAPACITORS ELECTROLYTIC – VALUE / WORKING VOLTAGE
R1 100k/5/0·33
R2 68k/5/0·33
R3 4k7/5/0·33
IC1 4001
IC2 4011
IC3 4027
IC4 4042
IC5 4050
IC6 4042
IC7 4050
IC8 4001
IC9 4011
IC10 4011
IC11 4042
IC12 4001
IC13 4042
IC14 4050
IC15 4027
IC16 4027
IC19 4050
IC24 4050
R5 & R6 5k6/5/0·33
R7 68k/5/0·33
R8 68k/5/0·33
R9 100k/5/0·33
R10 100k/5/0·33
R11 100k/5/0·33
R12–19 68k/2
R20–34 100k/2
R35–42 68k/2
R43 33k/5/0·33
R44 68k/5/0·33
R45 68k/5/0·33
R46
R47
R48
R49–56 68k/2
R57–64 68k/2
R65–72 68k/2
R73–80 68k/2
R81–88 68k/2
R89–96 68k/2
R97–104 68k/2
R105–112 68k/2
R113–120 68k/2
R121–128 68k/2
R129–136 68k/2
R137–144 68k/2
R145–152 68k/2
R153–160 68k/2
R161–168 68k/2
R169–176 68k/2
R177–184 68k/2
R185–192 68k/2
R193–200 68k/2
R201–208 68k/2
R209–216 68k/2
R217–224 68k/2
R225–232 68k/2
R233–240 68k/2
R241–248 68k/2
R249–256 68k/2
R257–264 68k/2
R265–272 68k/2
R273–280 68k/2
R281–288 68k/2
R289–296 68k/2
R297–304 68k/2
R305–312 68k/2
R313–320 68k/2
R321–328 68k/2
R329–336 68k/2
R337–344 68k/2
R345–352 68k/2
R353–360 68k/2
R361–368 68k/2
R369–376 68k/2
R377–384 68k/2
R385–392 68k/2
R393–400 68k/2
R401–408 68k/2
R409–416 68k/2
R417–424 68k/2
R425–432 68k/2
R433–440 68k/2
R441–448 68k/2
R449–456 68k/2
R457–464 68k/2
R465–472 68k/2
R473–480 68k/2
R481–488 68k/2
R489–496 68k/2
R497–504 68k/2
R505–512 68k/2
R513–520 68k/2
R521–528 68k/2
R529–536 68k/2
R537–544 68k/2
R545–552 68k/2
R553–560 68k/2
R561–568 68k/2
R569–576 68k/2
R577–584 68k/2
R585–592 68k/2
R593–600 68k/2
R601–608 68k/2
R609–616 68k/2
R617–624 68k/2
R625–632 68k/2
R633–640 68k/2
R641–648 68k/2
R649–656 68k/2
R657–664 68k/2
R665–672 68k/2
R673–680 68k/2
R681–688 68k/2
R689–696 68k/2
R697–704 68k/2
R705–712 68k/2
R713–720 68k/2
R721–728 68k/2
R729–736 68k/2
R737–744 68k/2
R745–752 68k/2
R753–760 68k/2
R761–768 68k/2
R769–776 68k/2
R777–784 68k/2
R785–792 68k/2
R793–800 68k/2
R801–808 68k/2
R809–816 68k/2
R817–824 68k/2
R825–832 68k/2
R833–840 68k/2
R841–848 68k/2
R849–856 68k/2
R857–864 68k/2
R865–872 68k/2
R873–880 68k/2
R881–888 68k/2
R889–896 68k/2
R897–904 68k/2
R905–912 68k/2
R913–920 68k/2
R921–928 68k/2
R929–936 68k/2
R937–944 68k/2
R945–952 68k/2
R953–960 68k/2
R961–968 68k/2
R969–976 68k/2
R977–984 68k/2
R985–992 68k/2
R993–1000 68k/2
C1 100p/2
C2 100p/2
C3 100n/50 ±20
C4 100n/50 ±20
C5 100n/50
W/F. I/P. 1
C/L. LATCH 2
R/D/G. 3
D.F. 5
19999 6
INT. 7
O/R. 8
U/R. 9
OV. 10
W/F. EX. 11
O/R. EX. 13
C/L DATA. 1 8 4 2 1 8 4 2 1 8 4 2 1 8 4 2 1 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
D.F O/R 31
Q2 32
–10V 33
R/D/G DATA. 1 8 4 2 1 8 4 2 1 8 4 2 1 8 4 2 1 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
R/S 51
+5V 54
+15V 55
200 KHz 56
2 KHz (4) 57
P4 58
2 KHz (9) 59 199x 60


DISPLAY
LM1
LAMPS 1-6
LAMPS 7-12
DISPLAYS 1-5
DISPLAYS 6-10
SECTION 'X-X'
SECTION 'Y-Y'
VIEW ON ARROW 'A'
8.7
23.1
6.1
21
A/R

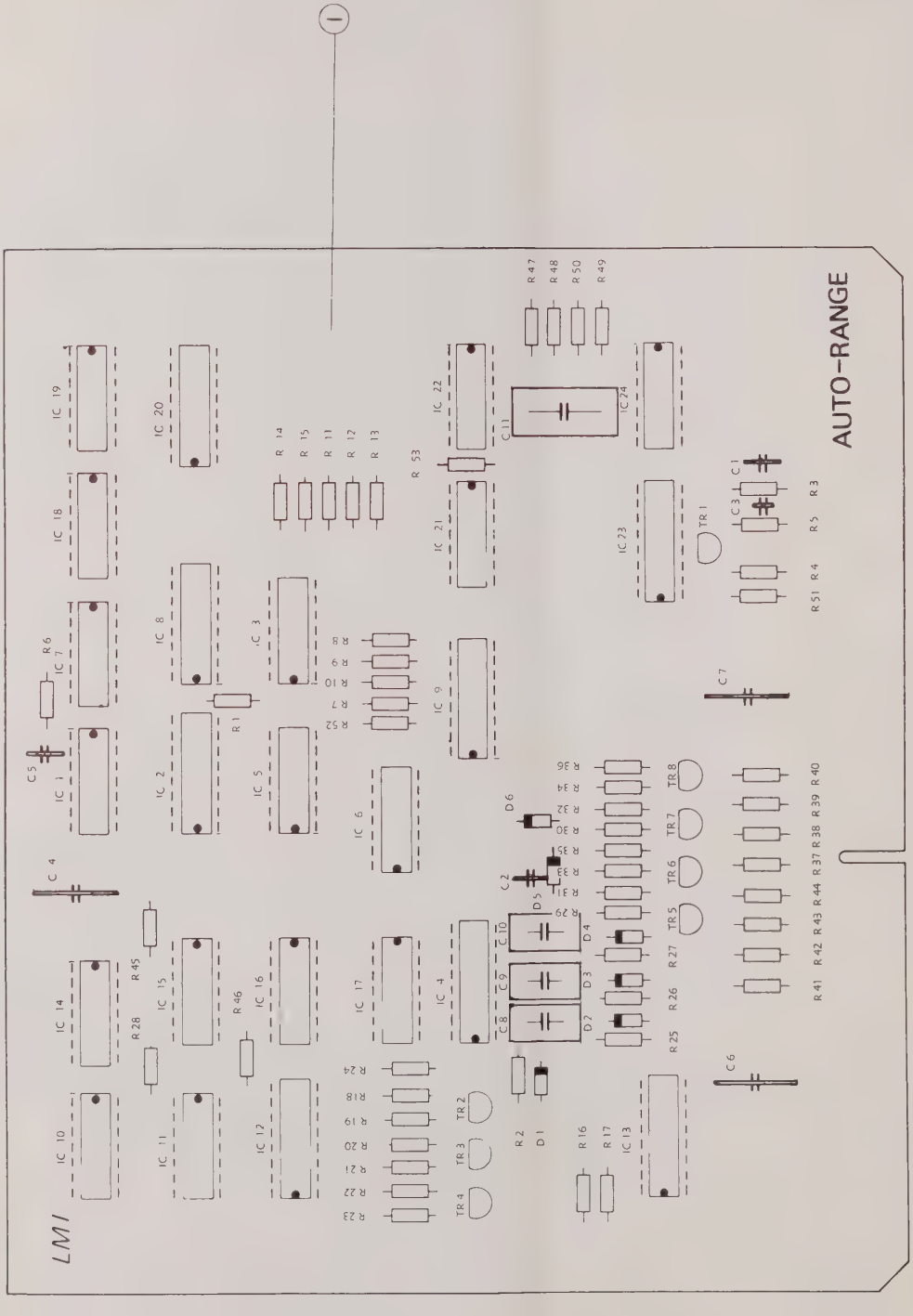

TR1 BC183
TR2 BC183
TR3 BC213
TR4 BC213
TR5 BC213
TR6 BC213
TR7 BC213
TR8 BC213
TR9 BC213
TR10 BC213
TR11 BC213
TR12 BC213
TR13 BC213
TR14 BC183
TR15 BC183
TR16 BC183
TR17 BC183
D1 IN4148
D2 IN4148
D3 IN4148
D4 IN4148
D5 LED
S1
IC1 7447
IC2 7447
IC3 7447
IC4 7447
IC5 PROM 1 825123
IC6 PROM 2 825123
IC7 7447
IC8 7447
IC9 7447
IC10 7447
μH mH H
μF nF pF
Ω kΩ MΩ
S mS μS
R1 270R/5/0·33
R2 270R/5/0·33
R3 270R/5/0·33
R4 47k/5/0·33
R5 270R/5/0·33
R6–R12 270R/2
R13 270R/5/0·33
R14–R20 270R/2
R21 270R/5/0·33
R22–R28 270R/2
R29–R35 270R/2
R36 3k3/5/0·33
R37 3k3/5/0·33
R38 27k/5/0·33
R39 47k/5/0·33
R40 4k7/5/0·33
R41 27k/5/0·33
R42 47×15/0·33
R43 4k7/5/0·33
R44 270R/5/0·33
R45 270R/5/0·33
R46 270R/5/0·33
R47 270R/5/0·33
R48 270R/5/0·33
R49 47k/5/0·33
R50 330R/5/0·33
R51–R57 270R/2
R58–R64 270R/2
R65–R71 270R/2
R72–R78 270R/2
R79 3k3/5/0·33
R80 3k3/5/0·33
R81 68k/5/0·33
R82 5×6/5/0·33
C1 100n/+50 −20
+5V 0V W/F EX. C/L. DATA RANGE 1 2 4 C R/D/G. DATA D.F. SWITCH D.F. +5V C/L DISPLAY BLANK G R/D SKT8
4 9 10 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 52 53 54 59 60
CIRCUIT REFERENCE CODING
RESISTORS VALUE/TOL±/WATTAGE 4k7 = 4·7k 680R = 680Ω
CAPACITORS VALUE/TOL ± 4n7 = 4·7nF
CAPACITORS ELECTROLYTIC VALUE/WORKING VOLT

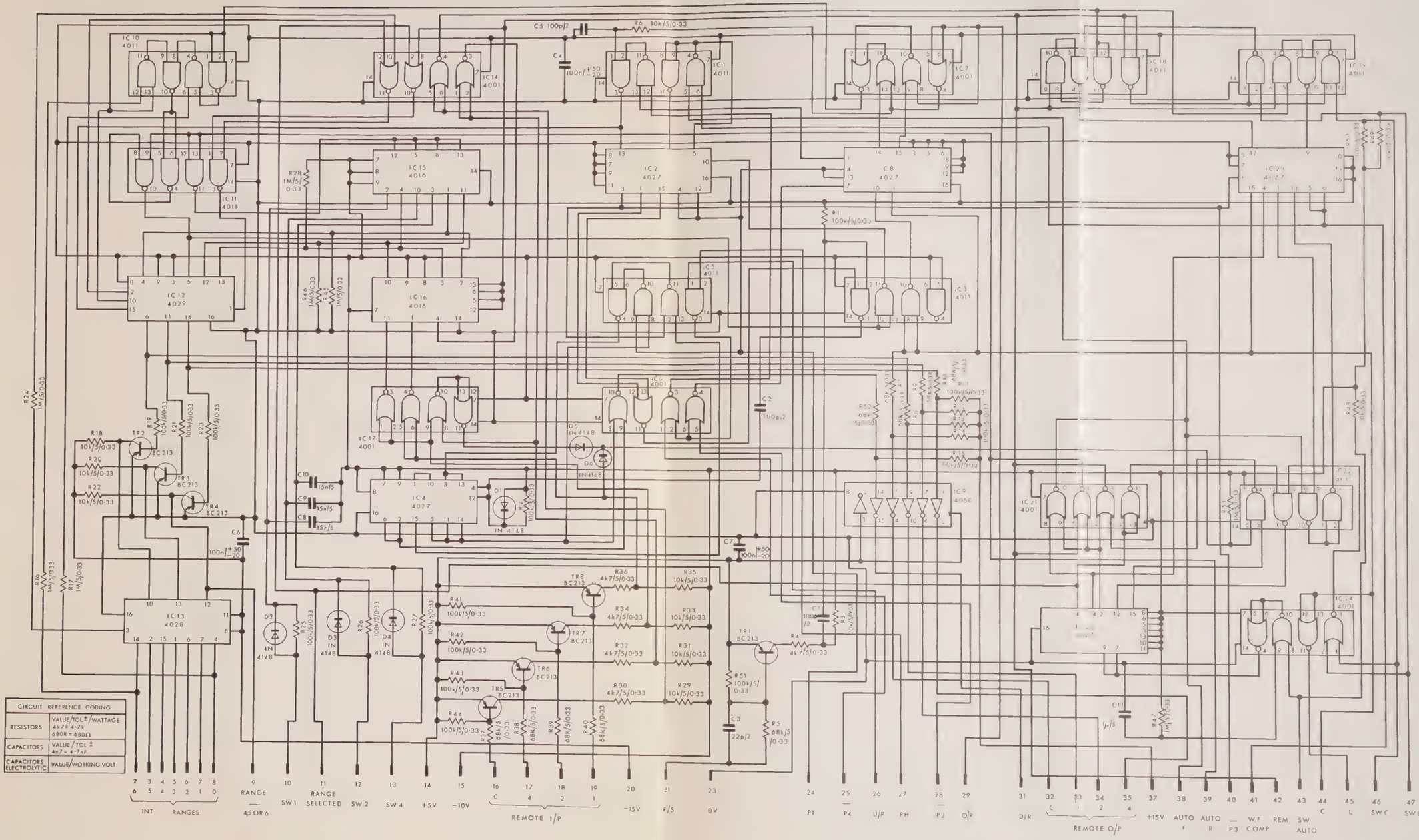
10.7 Switch Printed Circuit Board Lay-out



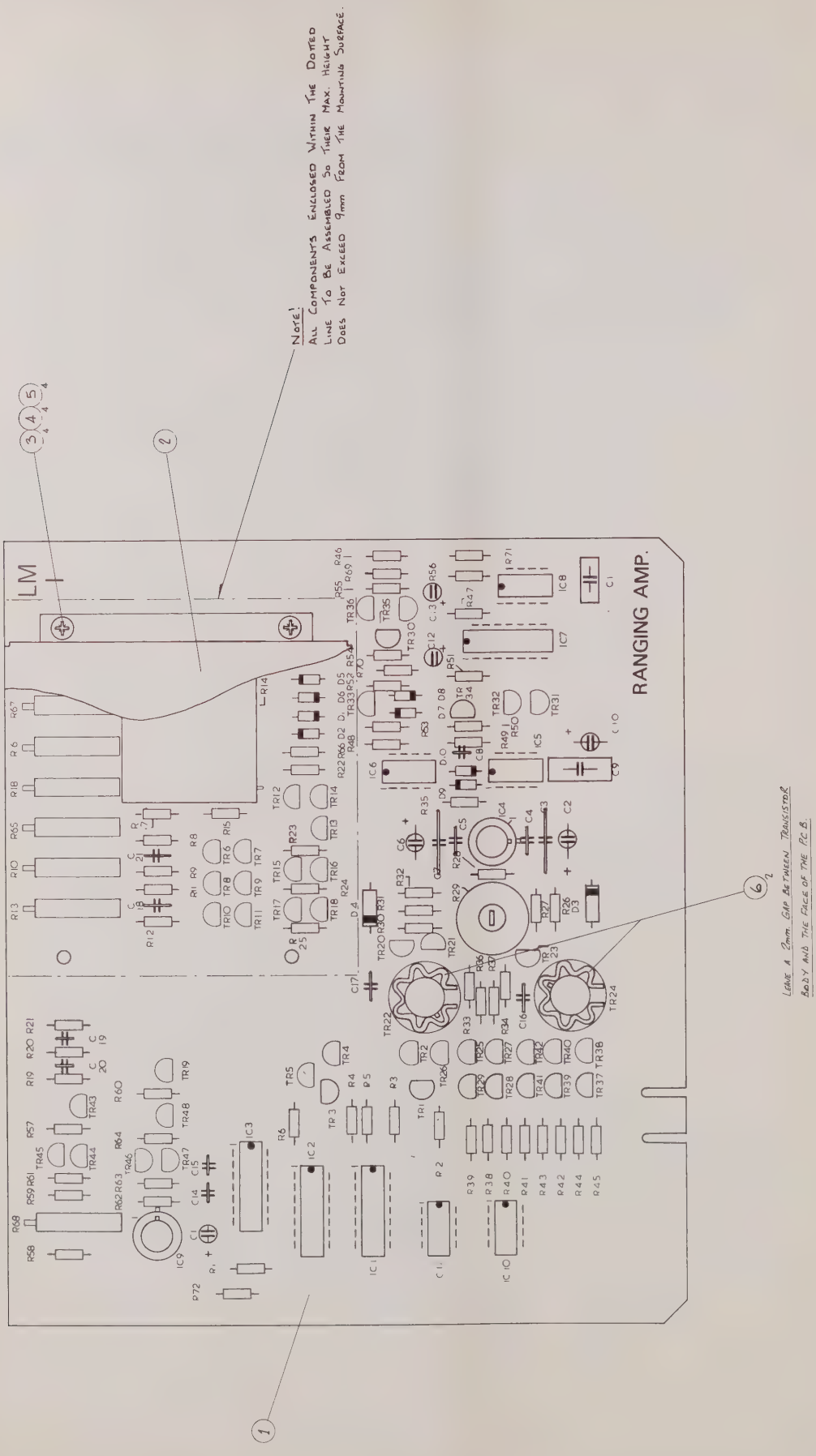

INT. RANGE
PIN NOS. 2 3 4 5 6 7 8
RANGE SELECTED
11
SW1 SW2 SW4 +5V −10V 0V
10 12 13 14 15 23
PIN Nos. A/F A/R REM. AUTO. C L SWC. SWL
38 39 42 43 44 45 46 47
CIRCUIT REFERENCE CODING
RESISTORS VALUE TOL± /WATTAGE 4x7 = 4·7k 680R = 680Ω
CAPACITORS VALUE / TOL ± 4n7 = 4·7nF
CAPACITORS ELECTROLYTIC VALUE/WORKING VOLT

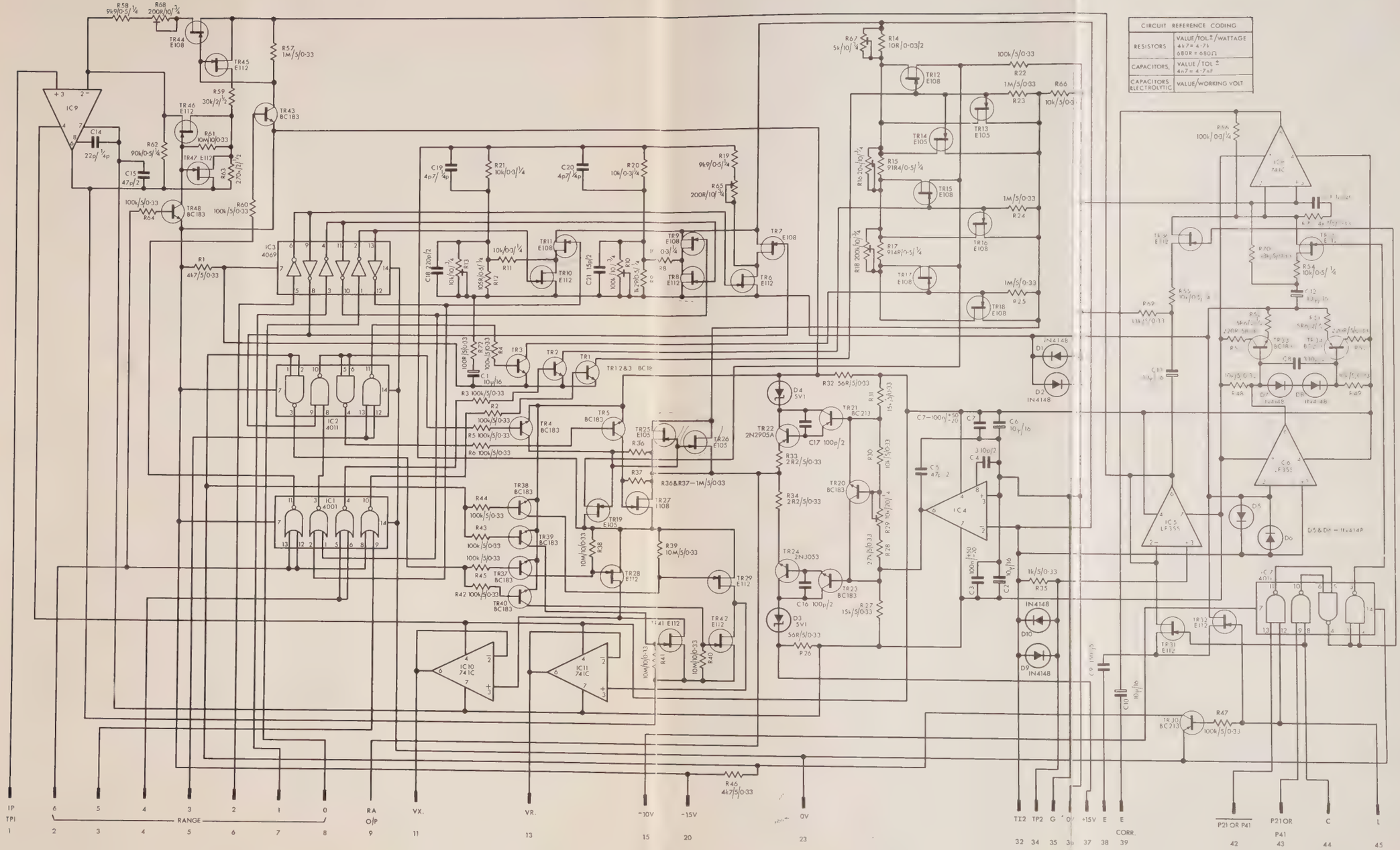
10.8 Auto-Range and Function Logic Printed Circuit Board Lay-out



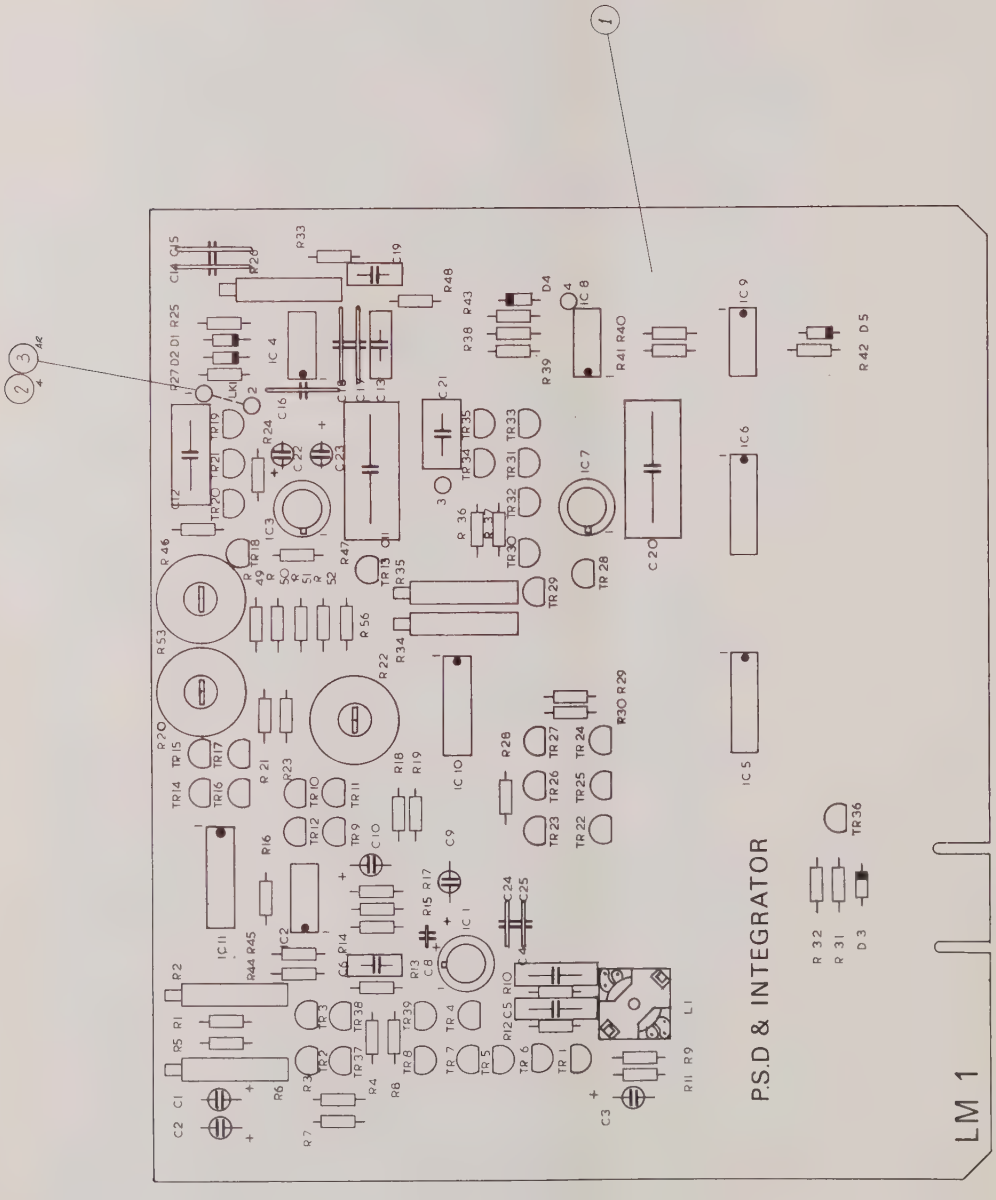

CIRCUIT REFERENCE CODING
RESISTORS VALUE/TOL±/WATTAGE 4k7=4·7k 680R=680Ω
CAPACITORS VALUE/TOL± 4n7=4·7nF
CAPACITORS ELECTROLYTIC VALUE/WORKING VOLT
INT RANGES
RANGE — 45 OR 6
SW1
RANGE SELECTED
SW.2
SW 4
+5V
−10V
REMOTE I/P
−15V
F/S
0V
P1
P4
U/R
FH
P2
O/P
D/R
REMOTE O/P
+15V
AUTO F
AUTO R
P3
W.F COMP
REM SW AUTO
C
L
SW C
SW L

10.9 Ranging Amplifier Printed Circuit Board Lay-out

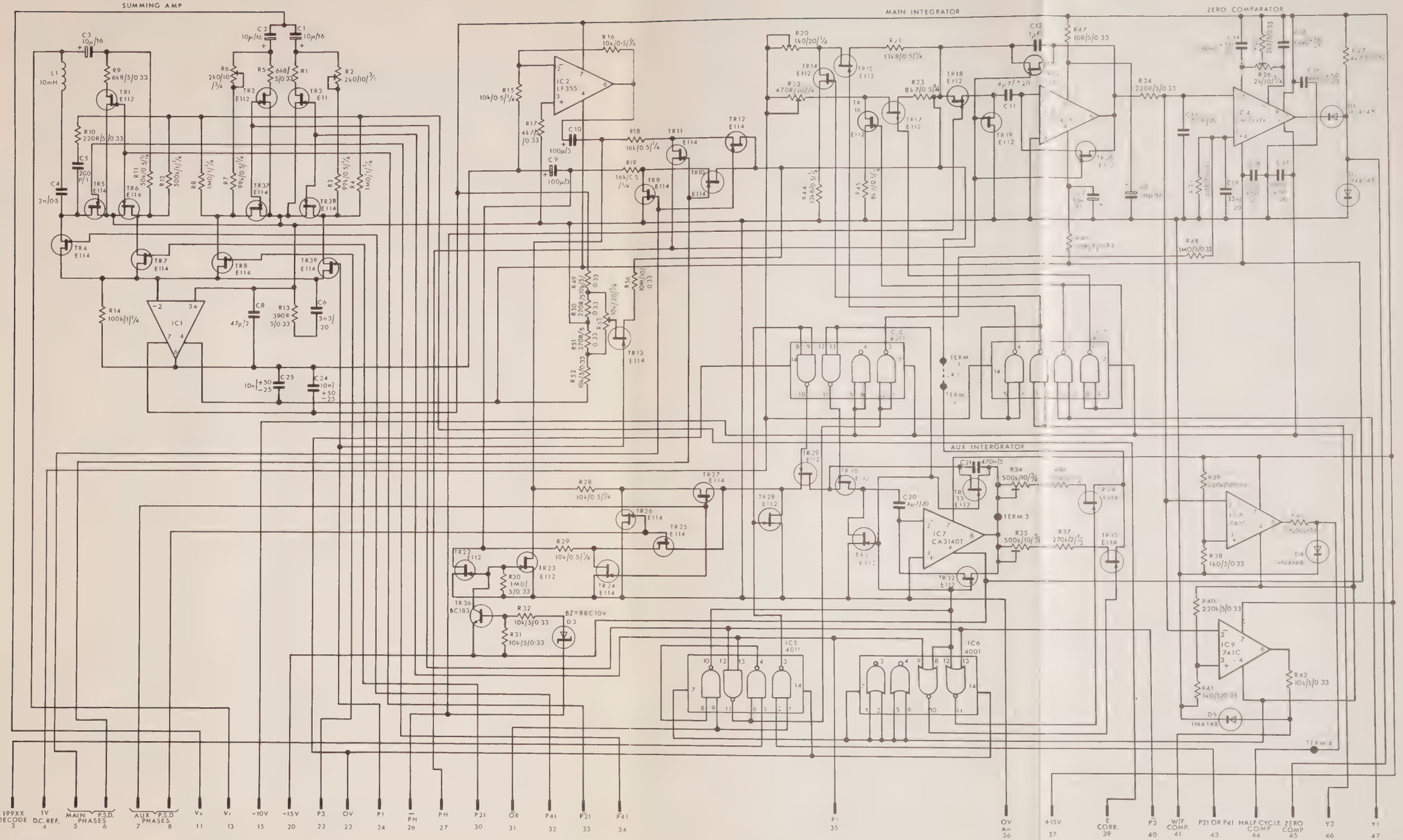

Note!
All Components Enclosed Within The Dotted Line To Be Assembled So Their Max. Height Does Not Exceed 9mm From The Mounting Surface.
LM
RANGING AMP.
Leave A 2mm Gap Between Transistor Body And The Face Of The PC.B.


CIRCUIT REFERENCE CODING
RESISTORS
VALUE/TOL±/WATTAGE
4k7 = 4·7k
680R = 680Ω
CAPACITORS
VALUE/TOL ±
4n7 = 4·7nF
CAPACITORS ELECTROLYTIC
VALUE/WORKING VOLT
IP
TPI
RANGE
RA O/P
VX.
VR.
-10V
-15V
0V
TI2
TP2
G
+15V
E
E
CORR.
P21 OR P41
P21 OR P41
C
L

10.10 Phase Sensitive Detector Printed Circuit Board Lay-out

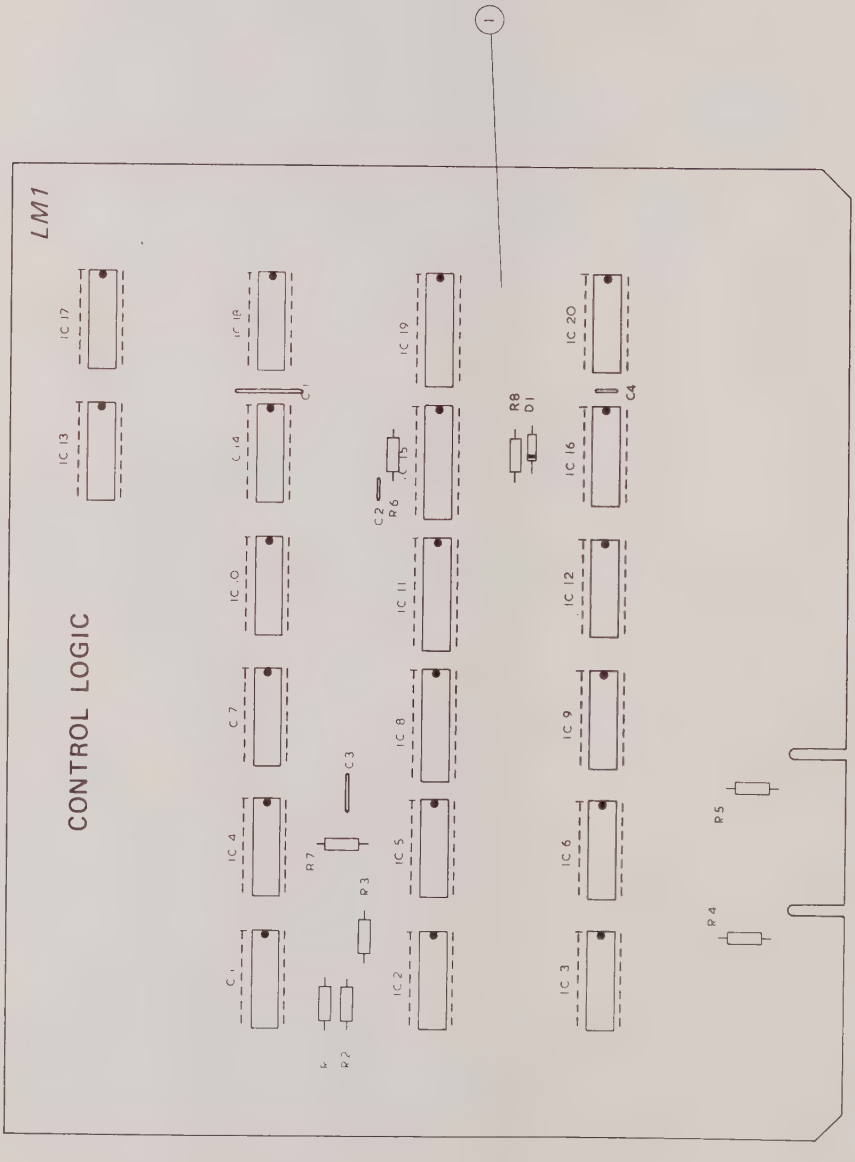


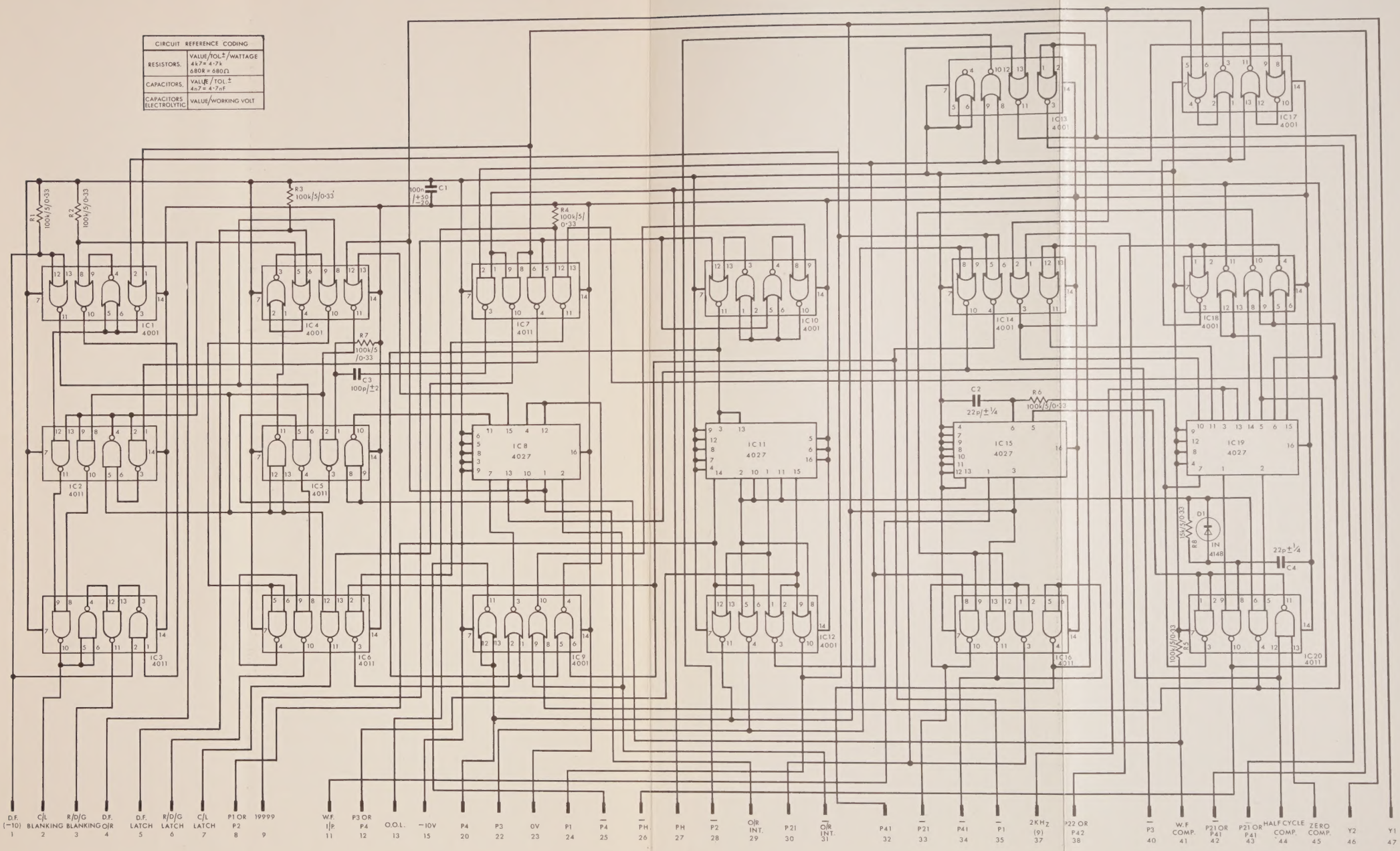
10.10 Phase Sensitive Detector Circuit Diagram



CIRCUIT REFERENCE CODING	
RESISTORS	VALUE/TOL±/WATTAGE 4k7 = 4·7k 680R = 680Ω
CAPACITORS	VALUE/TOL ± 4n7 = 4·7nf
CAPACITORS ELECTROLYTIC	VALUE/WORKING VOLT

10.11 Control Logic Printed Circuit Board Lay-out




CIRCUIT REFERENCE CODING
RESISTORS. VALUE/TOL±/WATTAGE 4k7 = 4·7k 680R = 680Ω
CAPACITORS. VALUE/TOL± 4n7 = 4·7nF
CAPACITORS ELECTROLYTIC. VALUE/WORKING VOLT
R1 100k/5/0·33
R2 100k/5/0·33
R3 100k/5/0·33
100n/+50/−20 C1
R4 100k/5/0·33
R7 100k/5/0·33
C3 100p/±2
C2 22p/±¼
R6 100k/5/0·33
D1 IN 4148
R5 150k/5/0·33
C4 22p/±¼
R8 100k/5/0·33
IC1 4001
IC2 4011
IC3 4011
IC4 4001
IC5 4011
IC6 4011
IC7 4011
IC8 4027
IC9 4001
IC10 4001
IC11 4027
IC12 4001
IC13 4001
IC14 4001
IC15 4027
IC16 4011
IC17 4001
IC18 4001
IC19 4027
IC20 4011
D.F. (−10) 1
C/L BLANKING 2
R/D/G BLANKING 3
D.F. O/R 4
D.F. LATCH 5
R/D/G LATCH 6
C/L LATCH 7
P1 OR P2 8
19999 9
W.F. I/P. 11
P3 OR P4 12
O.O.L. 13
−10V 15
P4 20
P3 22
0V 23
P1 24
P4 25
PH 26
PH 27
P2 28
O/R INT. 29
P21 30
O/R INT. 31
P41 32
P21 33
P41 34
P1 35
2KHz (9) 37
P22 OR P42 38
P3 40
W.F COMP. 41
P21 OR P41 42
P21 OR P41 43
HALF CYCLE COMP. 44
ZERO COMP. 45
Y2 46
Y1 47

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